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THE USE OF RADIOACTIVE ISOTOPES FOR THE STUDY OF LITTORAL DRIFT

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In coastal and fluvial engineering works it is sometimes necessary to know in what way and in what quantities sand and mud at a given location will be transported by currents and waves. This problem is of great significance in the Netherlands Delta Project. The comprehensive programme of measurements set up by the Dutch Rijkswaterstaat **) *to follow the gradually changing hydrographic situation around the coast includes direct measurements of sand movements by means of radioactive tracers. Compared with other tracer applications this involves the use of large amounts of radioactive materials; careful preliminary investigations were therefore required to decide on questions of procedure and radiation protection.*

Introduction

The movement of sand and mud by water currents has been a factor of vital importance to man's settlements on the coasts since the earliest times. As a result of silt accretion from rivers and ocean current, harbours like Pisa and Bruges have come to lie far inland, whilst others, whose names are now scarcely remembered, such as Reimerswaal, have been undermined by erosive currents and have vanished into the sea. Others, too, have been preserved from the consequences of coastal detrition and siltation by human intervention. An illuminating example is Venice, of which the story goes that, by diverting the course of the River Brenta, which threatened to silt-up the lagoon, it was able to preserve its strategic position as an island city and port — at the expense of its vassal township Chioggia. However, we do not need to look so far back for examples of works for controlling sand and mud movements. The position of the Netherlands largely depends on such works, whether they concern land reclamation, as in the north of the country, or, as in the south-west, the protection of the coast and the keeping open of waterways by piers, groynes, etc.

It may well be that the execution of the Delta Project will call for new and extensive works of this kind. The envisaged damming of the estuaries (*fig. 1*), already begun, will reduce the length of the dykes to be defended against the tides from 1700 to about 1350 kilometres. At the same time, however, the damming will cause drastic changes in the hydrographic situation of this coastal area, particularly in the "underwater delta" adjoining the mouths of the estuaries. The currents in and out of the mouths, at right-angles to the coastline, will largely disappear, but the remaining currents parallel with the shore will bring about sediment displacements different from those known hitherto. The resultant change in the depth contours will in turn alter the configuration of the currents and also the wave phenomena, so important to sand and shingle movements, on the coast. The altered situation must at all costs be prevented from leading to the undermining and disintegration of the sand-dune foreshores, or blocking of the inlets to the Westerschelde and Rotterdam waterways.

The expected changes in sand movements along

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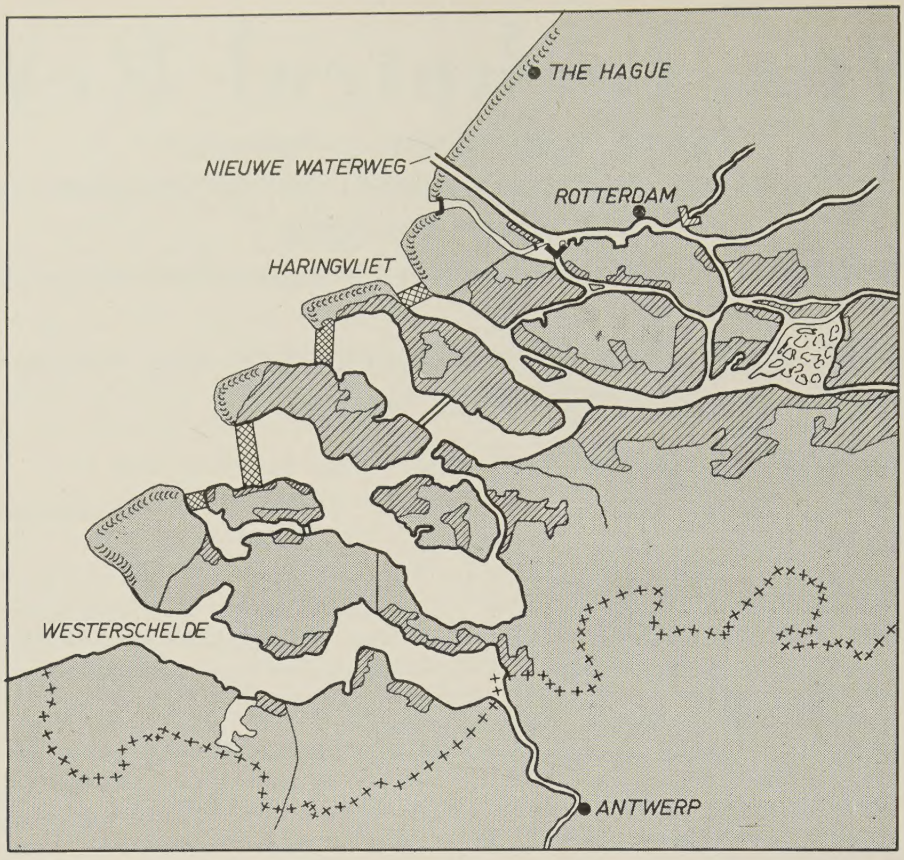

Fig. 1. Survey of the Dutch Delta Project, showing the projected damming of the estuaries. The damming of the Haringvliet is already in an advanced stage. Dykes that are at present still exposed to the action of tides are outlined in bold lines. The hatched parts indicate the areas inundated during the flood disaster in 1953.

Sand dunes along the coast.

Projected dams closing the estuaries.

Storm gate in the Hollandse Yssel.

Dams needed for implementing the coastal protection works.

Dams designed to improve the estuary conditions.

Storm gate in the Oude Maas, open during storm tides.

the south-west coast can be predicted to some extent on theoretical grounds. The picture presented by such predictions is not unfavourable, but the uncertainties involved are very considerable. The transport of sediment, which takes place partly on the river and sea beds and partly in the water itself (where sediment particles are present in suspension) is a much too complex phenomenon for exact calculation, being governed not only by permanent and quasi-permanent two-dimensional currents and by wave action but also by local disturbances, turbulence, the Coriolis force and, at bends, by centrifugal forces. Again, the configuration of currents and waves themselves, being determined by numerous factors including the tides, fluvial discharges, differences of density in the water and winds, is something that can only be learned from measurements [1]).

For the purposes of the Delta Project it was therefore necessary to make an extensive and largely experimental study of littoral drift in the coastal areas concerned. The investigations are in part being carried out on scale models in hydrological laboratories. A large model of the Haringvliet (horizontal scale 1 : 150), which will be the first of the sea inlets to be closed, has been the subject of experiments for some considerable time now at De Voorst, and another model, covering a coastal belt from the Haringvliet to beyond the mouth of the

[1]) For a further discussion of this question see the Delta Authority's Progress Report of June 1957 (also published as Technical Memorandum No. 105 of the Beach Erosion Board, March 1958): J. J. Arlman, P. Santema and J. N. Svašek, "Movement of bottom sediment in coastal waters by currents and waves; measurements with the aid of radioactive tracers in The Netherlands." Many of the considerations and experiments described here are discussed at greater length in this report.

Rotterdam Waterway (horizontal scale 1 : 800), was completed and taken into use in 1958 at Delft. Moreover, since various factors, such as wave action, cannot be simulated exactly in such models, "field experiments" are being carried out during the Delta works and will be continued after their completion. These experiments fall into three categories.

First, the *causes* of the sand movements are measured, namely currents and waves (which must also be known for other reasons). The measurements are made at fixed times in numerous places simultaneously, and constitute snapshots, as it were, of the current and wave conditions (height and spectral distribution of the waves) prevailing at given instants in the entire region under investigation. Extensive use is made of modern methods, such as the automatic transmission by radio of recorded data from fixed measuring points to an information centre (telemetering) and charting the position of test boats, of freely drifting rafts and even of wave crests by means of an 8 mm radar installation [2]).

The second category of measurements concerns the *consequences* of the sand movements: in a number of 500 metre strips along the coast extending from the foreshore to a depth contour 10 m below the mean sea level (Amsterdam datum level) (*fig. 2*), changes of the coast profile are studied from monthly soundings and analysed samples of bottom sediment.

In the third category the *actual process* of the sand movement is measured directly. This was made a practical possibility by a highly effective measuring technique developed during the last decade or so, and based on the use of radioactive tracers. When the sand at a particular site of the river or sea bed is "labelled" with such a tracer it is possible, owing to the high sensitivity inherent to radioactive measuring techniques, to detect some time later the presence of radioactivity in the sand at fairly considerable distances from that site, and in this way to track the movement of the sand. Quantitative data on sand transport can be obtained in this way. Details of this method and the problems it involves, some of which have been jointly investigated by the Delta Authority under the Dutch Rijkswaterstaat and the Isotope Laboratory of N.V. Philips-Duphar, will be discussed in the present article.

[2]) A similar 8 mm system is described in: J. M. G. Seppen and J. Verstraten, An 8 mm high-resolution radar installation, Philips tech. Rev. **21**, 92-103, 1959/60 (No. 3). A provisional communication on the use of radar in this connection will be found in the quarterly report "Deltawerken" No. 4, May 1958, pp. 11-19 (in Dutch).

Other and essentially simpler methods exist for directly measuring littoral drift. There is the "Sfinx" meter for the movement of bottom sediment and the "Delft flask" for the transport of particles in suspension, both based on the collection of moving sand in a calibrated vessel [1]). The results obtained with these and similar contrivances show very wide spreads, however, partly because the setting-up of the instrument affects the local state of flow in a manner that is difficult to ascertain. A further drawback is their limited usefulness in rough weather, precisely when sand movements may be most pronounced.

Principle of the method

A physical or chemical process in a given material can be investigated by means of a "tracer" of any kind, provided the tracer behaves in regard to the process in the same way as the material in question. In our case, then, the tracer must be a granular material that is transported by water in the same way as sand, or, to be more exact, as the sand found in the coastal area of the Delta works.

Supposing we already have such a tracer, the method of going about the measurements will be roughly as follows. A quantity of the tracer, possibly mixed beforehand with the ordinary unmarked sand, is carefully dumped at a given moment on to a certain site of the sea bed. Currents and wave action will now spread out this "tracer bed" over a large area. The requirement is that the tracer should later be detectable up to a distance of, say, 1000 metres from the dumping site. For the sake of argument we assume that the tracer has spread uniformly over a circle of 1000 m radius, thereby mixing with unmarked bed material to a certain depth d of, say, 10 cm. In that case the tracer concentration has been diluted by an amount of 300 000 cubic metres of unmarked sand.

Plainly, then, the measurements must be extremely sensitive in order to detect the tracer, and in our case, therefore, only radioactive tracers enter into consideration [3]). Even then, using the most sensitive of detectors, it remains necessary to work with enormously high levels of radioactivity. The following rough calculation will make this clear.

[3]) In principle the tracer used can also be a substance that differs from sand in its chemical or mineralogical properties, in its colour, or in its property of fluorescence. Quite apart from the inadequate sensitivity of these methods of analysis when the tracer is diluted to the extent mentioned above, or the expense involved, a drawback of such tracers is that samples from the sea or river bed have to be taken (which is *not* necessary with radioactive tracers). This makes measurements at numerous points a laborious and time-consuming process. Furthermore, repeated measurements in the same area are not possible with such tracers, since the tracer properties of the material remaining behind in the sediment (although very diluted) do not decay as is the case with radioactive tracers. See the account of the measurements below (pp. 160-166).

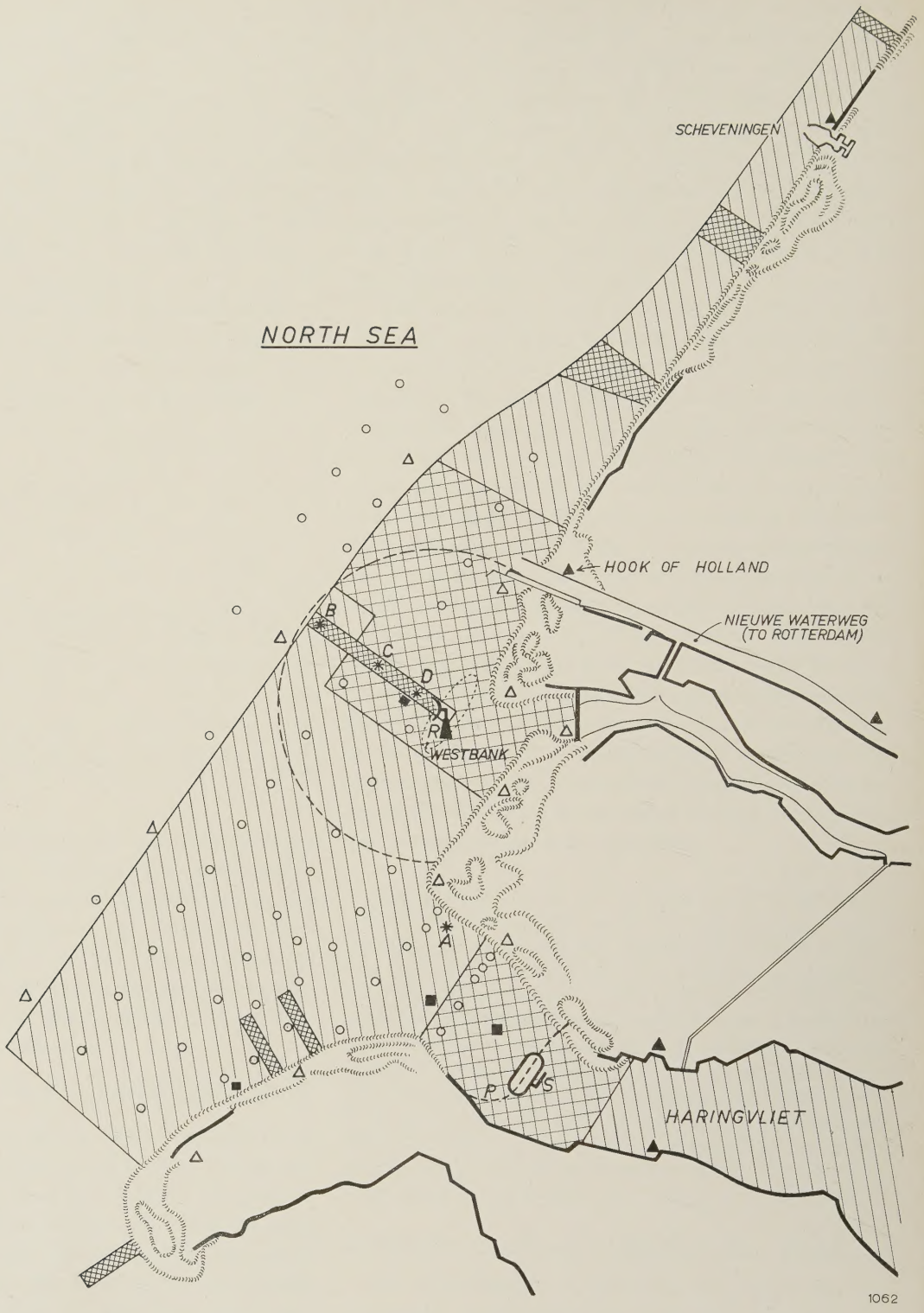

Fig. 2. Survey of the programme of measurements to be carried out during and after the damming of the Haringvliet. In the hatched sea-areas soundings will be made at regular intervals: ▨ once a year, ▩ several times a year, ▩ more frequently still. The symbols ▲ and ■ denote permanent recording stations for the tides, and for waves and tides, respectively. o places where currents will be measured; ✱ *ABCD* tracer dumping sites around which sand movements will be tracked by activity measurements; △ temporary stations for tidal measurements; *R* radar station; *S* sunk foundation for sluices in the Haringvliet; *P* course of dam proper.

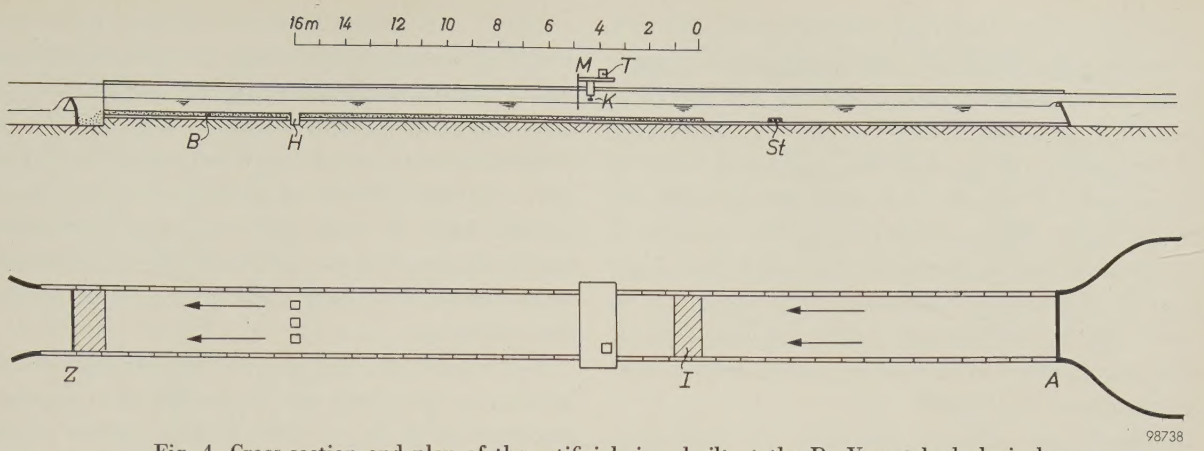

Fig. 4. Cross-section and plan of the artificial river built at the De Voorst hydrological laboratory in the North-East Polder. *A* water inlet, *Z* water outlet, *B* sand bed, *I* site where tracer material was dumped, *M* sliding bridge with scintillation counter *K* and instruments *T*, *H* sand traps for independent determination of sediment movement. At *St* a standard sample of tracer material was fixed and measured simultaneously during each test run, in order to allow for the gradual decline in tracer activity.

and the rate of flow (*fig. 4*). A scintillation counter, surrounded by a 300 kg lead shield to reduce interference from undesired radiation, was suspended from a wooden bridge capable of being slid along the banks. On top of the bridge were mounted the pulse-counting equipment (*fig. 5*), a dip-stick for reading the water level above the bed and a tube for drawing up samples of bottom sediment.

When the experiment was planned, similar experiments had already been carried out at two other places. The first concerned an investigation of

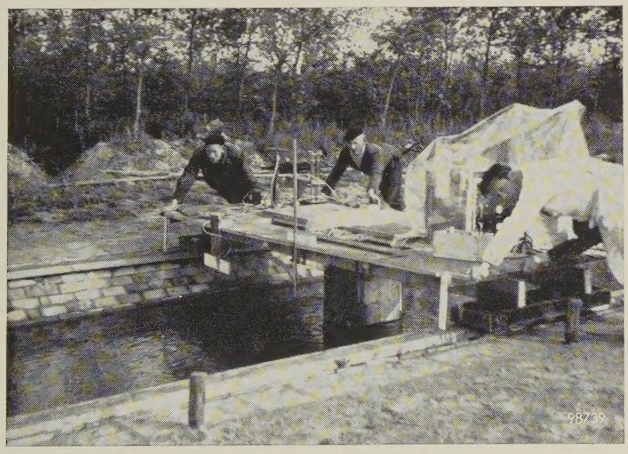

Fig. 5. Bridge with detector and instruments, used for the preliminary experiment at the De Voorst hydrological laboratory.

siltation in the Thames, and was made by members of the Atomic Energy Research Establishment, Harwell, in collaboration with the Port of London Authority [5]). Almost concurrently, Japanese investigators studied littoral drift along Hokkaido Island with a view to the building of a large harbour near the town of Tomakomai [6]). Since there was no possibility of suitably making sand grains themselves radioactive, use was made in both instances of powdered glass in which a radioactive isotope was fused (in England scandium, ^{46}Sc, and in Japan zinc, ^{65}Zn). Although it was to be predicted that the transport characteristics of glass grains would differ considerably from those of sand grains, a similar tracer was nevertheless chosen for our preliminary experiment, namely glass beads. In this case, however, instead of fusing an artificially radioactive substance into the glass, the glass beads were themselves made radioactive by irradiation in a nuclear reactor. Under neutron bombardment the radioactive isotope ^{24}Na is produced from the sodium in the glass; this isotope emits very hard gamma rays (1.38 and 2.76 MeV), and has a half-life of about 15 hours. This half-life is much too short for the large-scale investigations in the Delta area, where some measurements will extend over several weeks. For the preliminary experiment, however, a short half-life was just what was wanted in order to avoid the danger of prolonged radioactive contamination of the laboratory premises.

The tracer material was obtained by irradiating fifteen small aluminium cans, each containing 128 grams of glass beads, in the Dutch-Norwegian nuclear reactor at Kjeller, near Oslo. The irradiation lasted about a week, at the end of which time a total activity of 20 curies was measured (partly from shorter-lived isotopes than ^{24}Na).

Conveying the material from Kjeller to De Voorst was a problem in itself; it had, of course, to be done quickly, in view of the short half-life of ^{24}Na, and

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[6]) S. Inose, M. Kato, S. Sato and N. Shiraishi, The field experiment of littoral drift using radioactive glass sand, Proc. Conf. Peaceful Uses Atomic Energy, Geneva 1955, Part 15, p. 211.

at the same time thorough measures of radiation protection were necessary. Air transport was ruled out as too expensive. Road transport was therefore decided on. The containers were enclosed in a lead shield weighing 700 kg, and the truck was manned by three drivers who drove in shifts all through the day and night. The customs posts at the borders to be crossed (Sweden, Denmark, Germany) had been informed of the plan and gave every assistance to prevent delays. As a result, in spite of a breakdown on the road, there were still 1.5 curies of ^{24}Na left upon arrival at De Voorst.

Elaborate precautions attended the unloading of the trucks. A person standing about three feet away from the unshielded cans would have received in six minutes the maximum permissible dose for a whole week; moreover the special facilities available for handling radioactive material at the place of departure were lacking at De Voorst. The material was unloaded in an improvised dump consisting of a trench 50 metres long, access to which was barred on three sides by dense shrubs and brushwood. The cans were deposited at marked places a few yards apart so that in subsequent handling there was only the radiation from one can to be reckoned with. The contents of the first can were mixed with a known quantity of sand and water in a concrete-mixer, which was mounted on a plastic sheet for collecting spilt material. With a few simple tools the can could be opened in the mixer by remote operation. The labelled sand was then immediately conveyed to the artificial river and emptied out at the appropriate site (see *fig. 6*).

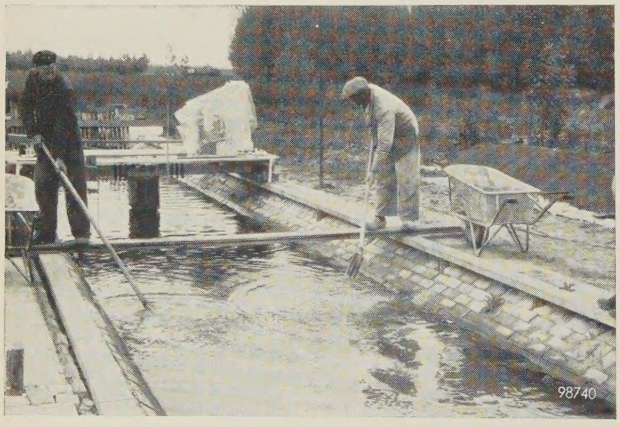


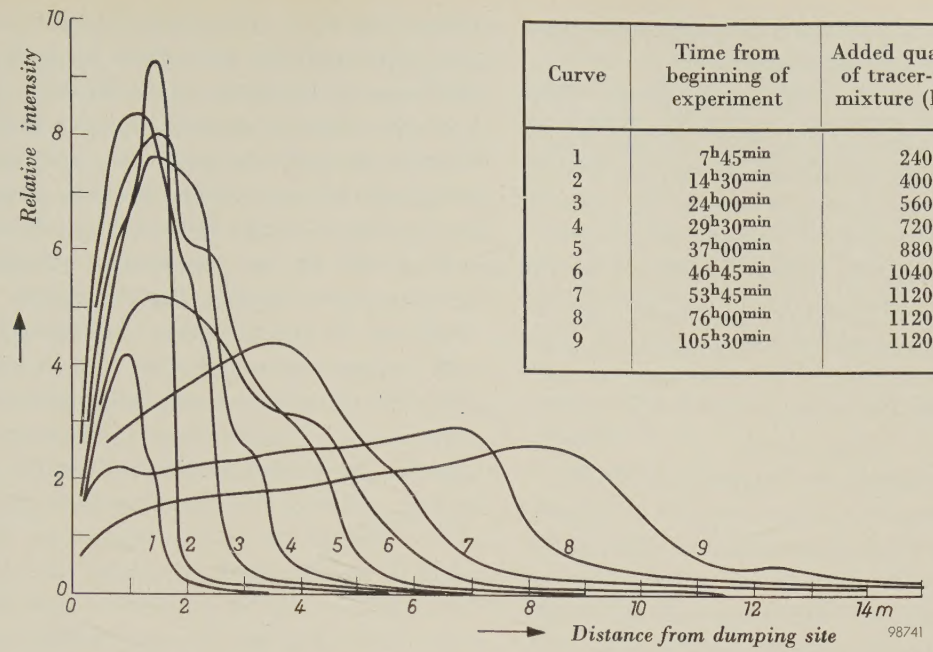
Fig. 6. Dumping the tracer in the artificial river.

This having been done, measurements were made at regular intervals of the distribution of activity along the axis of the channel over a length of about 15 metres. All results were reduced in the usual manner to percentages of a standard sample of the original radioactive material which was measured simultaneously, in order thus to correct for the gradual decline in radioactivity with time. A few hours later the same quantity of sand, labelled with glass beads from the second can, was dumped at the same site, and the activity measurements were then resumed. After 50 hours all the radioactive material had been used up in this way. The measurements were carried out for a total of 100 hours from the first dumping.

The results of the activity measurements made at various times over the length of the channel are represented in *fig. 7*. The broken curves in *fig. 8* show the rates of transport derived from these results (in litres of bottom sediment per hour), compared with the true rates of transport (full curves) which, because of the simple geometry of the channel, could be calculated from the measured changes in the configuration of the bed. It can be seen from the latter curves that at the beginning of the experiment there was virtually a steady-state movement of sediment; the quantities of sand carried away at the end of the length of channel tested were roughly equal to the quantities supplied to the dumping site. At this early stage, however, the transport of the glass beads clearly lagged behind that of the sand. As mentioned, a difference in this respect was to be expected: the average size of the glass beads was greater than that of the sand grains (D_{50}, that is the value of the diameter which is exceeded by 50% by weight of the material, was 270 μ for the glass beads as against 160 μ for the sand at De Voorst). Moreover, the size distribution of the grains was entirely different, and the specific gravity of the glass was 2.95 as against 2.65 for the sand. As can been seen from fig. 8, after the first 50 hours, when there was no longer a steady-state movement of sediment, but bed erosion or "scour" had set in, transport of the glass beads occurred. Previous to this, they had evidently largely remained behind with the larger of the sand grains.

Apart from giving a clear idea of the errors to be expected if the tracer material does not possess the same transport characteristics as the sand, the experiment demonstrated that the measuring technique employed can yield useful information on the distribution of radioactivity present in a given area, even when the activity is low (after 100 hours there remained only 1.5% of the original activity).

Numerous measures were taken to protect the personnel against radiation during the experiment. The radiation hazards involved in the various operations were checked by systematic monitoring. In



Curve	Time from beginning of experiment	Added quantity of tracer-sand mixture (litres)
1	7^h45^{min}	240
2	14^h30^{min}	400
3	24^h00^{min}	560
4	29^h30^{min}	720
5	37^h00^{min}	880
6	46^h45^{min}	1040
7	53^h45^{min}	1120
8	76^h00^{min}	1120
9	105^h30^{min}	1120

Fig. 7. Tracer activity as a function of distance from dumping site, measured at various times along the axis of the channel (fresh tracer material being added at regular intervals; see inset table).

some cases, for example during the operation of the concrete-mixer and when dumping the active sand, continuous monitoring was adopted. All persons engaged in the tests, including some unskilled workers, were of course thoroughly instructed on procedure beforehand. All wore film badges for checking the total received dose, and those most exposed also carried pocket dosemeters [7]) for measuring dose rates at appropriate moments. The area in which radioactive material was handled was plainly marked off by warning signs, and persons unconnected with the experiment were not allowed to enter. Radioactive contamination of the ground near the concrete-mixer could not entirely be avoided, but since the personnel wore either clogs or gum-boots which were left behind at the end of the day, no radioactivity was trodden outside. Moreover, the short life of ^{24}Na meant that all contamination of the premises had disappeared after about a week.

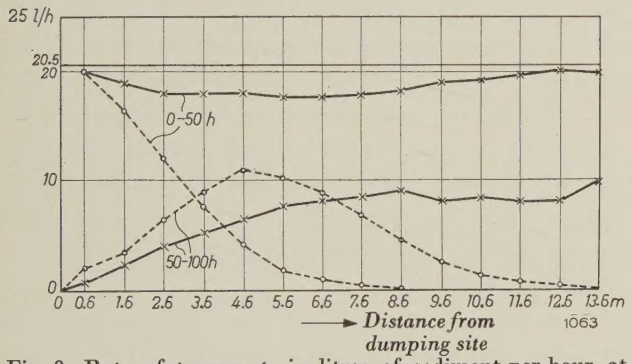


Fig. 8. Rate of transport, in litres of sediment per hour, at points along the axis of the channel in the first 50 hours of the experiment (during which fresh tracer material was repeatedly added at an average rate of 20.5 l/h) and in the following 50 hours (during which no further tracer was added). The broken curves are derived from the activity measurements, the solid curves from the changes in the configuration of the bed. The transport characteristics of the tracer (activated glass beads) differ considerably from those of the sand. This is particularly evident from the curves for 50-100 hours, which, in the first 6 metres, show a larger rate of transport of radioactive material than corresponds to the actual rate of sand transport there: initially, in this first 6 metres or so, the tracer grains were hoarded up, as it were, and only released when there was not much normal sand left over.

At the end of the experiments it was found that only a few persons had received a total dose in excess of 100 milliroentgens. The highest dose was 160 mr, received by those who had worked 3 days for 8 hours a day. At that time the permissible weekly dose was 300 mr [8]).

Labelling the sand for measurements on the coast

As we have seen, the simple method of using activated glass beads is not suitable for the definitive measurements. The half-life of ^{24}Na is also far too short. What is wanted is a half-life of the order of one week to a month; there is then sufficient time to carry out measurements extending over a few weeks, whilst on the other hand the activity decays quickly enough to avoid any cumulative conta-

[7]) See e.g. N. Warmoltz and P. P. M. Schampers, A pocket dosemeter, with built-in charger, for X-radiation and gamma radiation, Philips tech. Rev. **16**, 134-139, 1954/55.

[8]) The weekly permissible dose has since been reduced to an average of 100 mr, but peaks are allowed provided that the total dose received in 13 weeks does not exceed 3 r.

mination of beaches or interference with subsequent measurements in the same area.

Direct activation of a quantity of sea sand, by irradiation in a nuclear reactor, would be the ideal way of ensuring completely identical behaviour of the tracer in regard to its transport by currents and waves. In particular there would then also be a reasonable certainty that each grain had received an activity proportional to its weight; in that case the measured activities would be a direct measure of the displaced quantities of sand by weight, irrespective of the segregation between grains of different size that may occur during displacement. Unfortunately, for our purposes the elements present in sea sand either produce isotopes of too low an activity or they lead merely to beta emitters, whose radiation is not penetrating enough, and which moreover are short-lived. It was therefore necessary to look for a suitable radioactive isotope, and to find a means of bonding it or incorporating it chemically in sand, or in a substance sufficiently like sand for our purpose.

An investigation into the possibly suitable isotopes led to the choice of ^{46}Sc. This has a half-life of 85 days and emits two gamma quanta, one of 0.89 MeV and one of 1.12 MeV. The presence of two radiations of different energy can be an important advantage, for in principle it is then possible, by virtue of the different absorption of these radiations in the bottom sediment, to deduce from the measurements information on the activity distribution in a vertical cross-section of the sea bed. (This implies, however, that the semi-angle φ in fig. 3 would have to be rather small, which would reduce the sensitivity of the activity measurements.)

The isotope ^{45}Sc, from which the active ^{46}Sc is formed by neutron-capture, has an effective cross-section for this process of 22 barns; this is a relatively high value, and means that when a quantity of the material is irradiated in a nuclear reactor a quite considerable activity per unit weight can be produced. In view of the high total activity needed in our case (as mentioned above, as much as 40 curies may be required) this is a favourable circumstance, for there is only limited space in a reactor for the parent material and strongly radioactive materials become more difficult to handle as their volume increases.

There is no known method of bonding ^{46}Sc to grains of sand [9]). An effective and economical alternative, however, is to bond the isotope to an inorganic ion-exchange substance. In connection with their normal function — the binding of ions from a solution which is passed through a column packed with the ion-exchange material — the ion-exchange substances are prepared in the form of grains. Some have grains of nearly the same size as the sea sand with which we are concerned. Furthermore, the exchangers are capable of binding ions of trivalent scandium so strongly that subsequent exchanges with monovalent or divalent ions in sea water are negligible. For that reason substances of this kind, particularly of the clayish zeolite group, are in fact used for "cleaning-up" the radioactive waste from nuclear reactors, which is deposited at inaccessible places. One of the zeolites known as "greensand", which is commercially available as "Ionac C 50", has a density (2.72-2.76) close to that of North-Sea sand (2.65-2.68) and it can readily take up the necessary quantity of scandium.

The take-up capacity of Ionac C 50 cannot by any means be used to the full. Indeed, the activity per unit weight of tracer, that is to say the activity per grain of zeolite, must not be unduly high. There are two reasons for this. Firstly, they must not be injurious to humans or fish that may swallow some. Secondly, the activity must be carried by so many grains that even in the most diluted state of the tracer the statistical fluctuations in the number of grains present in the "field of view" of the scintillation counter will remain sufficiently small. Referring back to the foregoing calculation (see formula (1) and discussion following it), we can put the required number of grains for one measurement at 100. At the beginning of the experiment described we should then need a total of approximately 2.5×10^9 grains. If the average grain diameter is 200 μ, this means that the total initial activity of about 6 curies must be contained in at least 25 kg of the ion-exchange substance.

The activity per grain is then low enough not to cause any harm to fish, even though they may swallow large numbers of the widely dispersed grains. Sea bathers would have to consume kilograms of sea sand before their activity intake from the tracer in its ultimate dilution reached the permissible level. *A fortiori* the activity to which bathers lying on the beaches might be exposed is far below the permissible limit.

One difficulty, which typifies the whole experiment, was that the grains of Ionac C 50 are *softer* than the sand grains in which they are mixed. During the movement of sediment over the sea bed the grains are therefore *eroded* by the sand, their

[9]) This has, however, proved possible with ^{140}Ba, an isotope that might also be used for this purpose inasmuch as its daughter product ^{140}La emits hard gamma quanta. See D. B. Smith and J. D. Eakins, Unesco Conf. Radio-isotopes in sci. Res., Paris, Sept. 1957, paper No. 63.

size distribution changes rapidly, and the resultant segregation again causes the transport properties of the tracer to differ excessively from those of the sand. It is possible, however, to make the Ionac C 50 grains harder by firing the material at 750 °C. The capacity of the fired material to absorb ^{46}Sc, and the rate at which it does so, are still sufficient, allowing the active isotope to be added to the Ionac C 50 *after* firing, which is of course the easier procedure; the limited activity required per grain is absorbed in about 2 hours (the unfired grains absorb the same activity in 3 minutes). The fact that firing adequately reduces the erosion is demonstrated in *fig. 9*: a mixture of fired Ionac C 50 and quartz

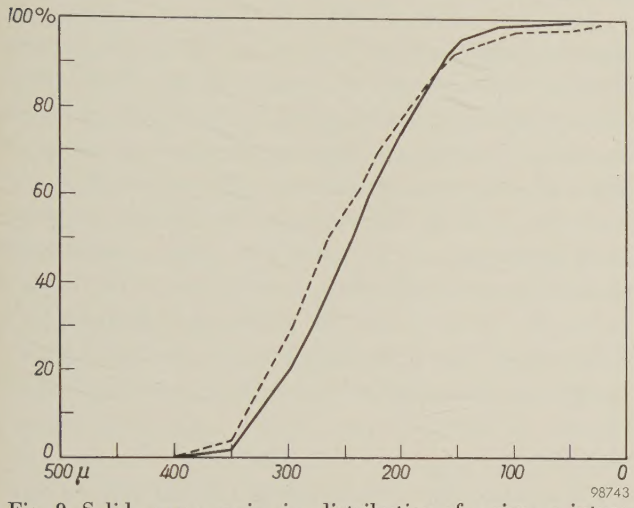


Fig. 9. Solid curve: grain size distribution of a given mixture of sand and fired "Ionac C 50" (the ion-exchange substance in which the radioactive isotope ^{46}Sc is absorbed), plotted as the percentage by weight of grains *larger* than the value on the abccissa. Broken curve: the distribution after the mixture, suspended in water, had been shaken up for 10 hours in a concrete-mixer. There is scarcely any change in the distribution, indicating that there is virtually no erosion of the fired Ionac C 50 grains by the sand.

sand was shaken up for 10 hours in a concrete-mixer, and the results show that the size distribution of the mixture remained reasonably constant. After the Ionac C 50 had been stirred in sea water for 48 hours, it was not possible to detect any drop in ^{46}Sc activity.

The measurements in the Delta coastal area are therefore being carried out with this tracer material.

The coastal measurements now in progress

In April 1958, trial measurements were made in the mouth of the Haringvliet (the tracer being dumped at point *A* in fig. 2). These provided an opportunity to test the method in the field, and at the same time yielded the first data on sand movements in this area, which is of particular importance to the Delta Project at the present stage.

Before the tracer material was dumped the area was scanned for radioactivity in order to determine the background to be allowed for during the measurements. This brought to light a number of unsuspected facts. The sand on the sea bed was found to possess much higher natural radioactivity than the sea water. This activity appears to be concentrated in the heavy minerals, which constitute from 1 to 5% of the sand, and is thought to originate from uranium or thorium inclusions in the mineral zirconium. Moreover, the background count rate from the sea bed differed considerably from place to place; the average background is about 200 counts per minute, but at some points it rises to 500 per minute. Even before the actual measurements (with the *artificial* tracer) were begun, therefore, it was possible to draw certain conclusions concerning sand movements, viz. to deduce at what places a relatively high content of heavy minerals and coarse grains of sand are deposited.

For introducing the radioactive isotope into the appropriate quantity of carrier material, an installation was erected on a barge; a photograph of the installation is shown in *fig. 10* and particulars are given in the caption [10]). The prepared material is deposited at the planned position from a small craft by means of a specially designed container, provided with a shield, which is let down vertically on to the sea bed to prevent the discharged material from being dispersed by the current before it has had time to settle.

The activity detector (a scintillation counter), properly shielded, is mounted on a sled two metres long (*fig. 11*), which is towed over the sea bed by a flat-bottomed boat. The detector thereby maintains

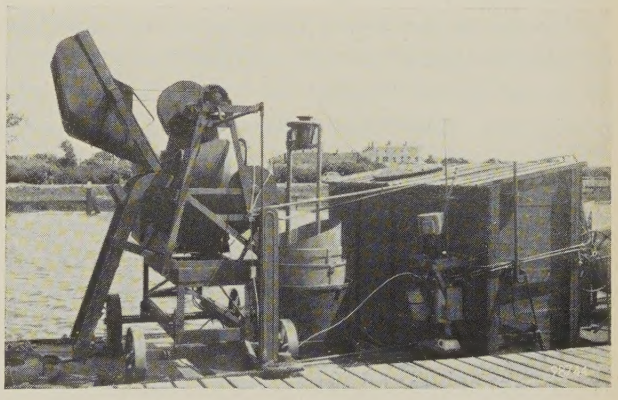


Fig. 10. Plant installed on a barge for preparing the tracer material [10]). An ampoule containing radioactive ^{46}Sc, prepared in a nuclear reactor, is broken open and the contents dissolved in nitric acid in a vessel (not visible in the photograph). The solution is neutralized and diluted with water, after which it is conveyed by compressed air to the mixer shown on the left, which contains the appropriate quantity of "Ionac C 50". After some hours of mixing the ^{46}Sc is distributed uniformly enough amongst the grains. The contents of the mixer are emptied into the container on the right of the mixer, in which the tracer material is conveyed to the dumping site. The large bunker on the extreme right is filled with sand to protect workers on the barge against radiation. The whole installation is remotely controlled from behind this bunker.

[10]) A description of the procedures in the field is given in quarterly report "Deltawerken" No. 6, Nov. 1958, pp. 22-28, from which figures 10-12 have been taken.

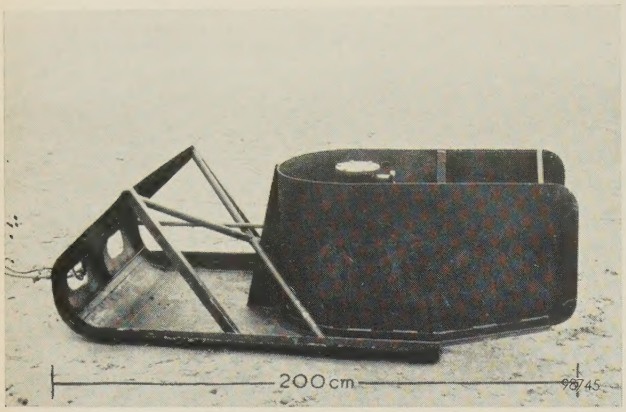


Fig. 11. Sled on which the scintillation counter and its shielding are mounted, and which is towed over the sea bed by a flat-bottomed boat. It is connected to the instruments on the boat by a 6-core cable.

automatically a constant distance of 20 cm above the surface of the sand (fig. 3). On board the boat are a count-rate meter and recording unit, together with a power supply unit which provides the 1700 to 2000 V constant potential for the detector. All this equipment is fed from a 220 V A.C. generator and is connected to the detector sled by a six-core cable.

The accuracy of the whole method is determined partly by the accuracy with which a fix is obtained on the position of the detector sled. Originally the boat was navigated as well as possible along a leading line defined by markers along the shores (*fig. 12*), and a fix of the boat's position on this line was obtained by means of a sextant. The Delta Authority now has at its disposal an apparatus for radio navigation, the "Decca Survey System", which

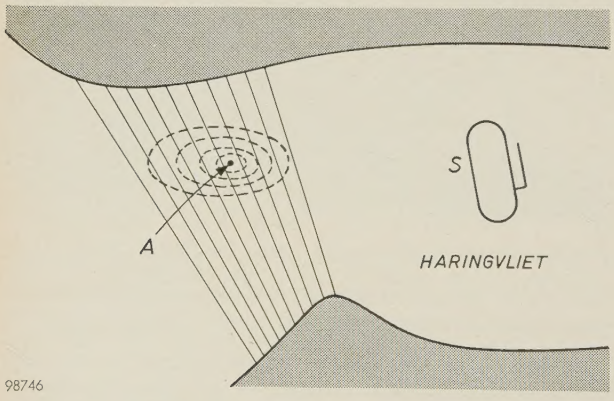


Fig. 12. Leading lines in the Haringvliet, defined by markers on the shores. The tracer material was dumped at *A*. The boat, while detecting and recording the radioactivity continuously, is steered as closely as possible along these lines so that with only one angular measurement a fix can be obtained on its position. The contours of equal activity, shown here by dotted lines, are determined by combining the results of all measurements taken at various times. This system of navigation has since been superseded by the "Decca Survey System", which is much more accurate.

was first used in 1944 during the Allied landings on the coast of Normandy. The system uses hyperbolic coordinates determined by three transmitters — situated at Rilland-Bath, at Sluis and at Schipluiden — and the navigator can fix his position in these coordinates from the readings of two indicating instruments on board the boat [11]). Within the estuaries this system has an accuracy of 3 to 4 metres, and outside them of 5 to 8 metres; with the old system the error in the fix could be as much as 20 metres. The position of the sled in relation to the boat is calculated from the length and sag of the towline and from the depth of the water, a correction being applied for the effect of the current.

In June 1959, large-scale measurements were started with the object of ascertaining the present littoral drift near the mouth of the Rotterdam Waterway. A total amount of roughly 300 kg of tracer material, having an activity of about 6 curies of ^{46}Sc, was deposited at three points marked *B*, *C* and *D* in fig. 2. It is expected that the results of these measurements, in conjunction with scale-model investigations, will allow conclusions to be drawn as to the effect which the building of Rotterdam's "Europoort" and the damming of the Haringvliet will have on conditions at the mouth of the Waterway.

[11]) Quarterly report "Deltawerken" No. 7, Feb. 1959, pp. 5-10.

Summary. The transport of sediment over sea and river beds by the action of currents and waves is of great importance to coastal and river works. During the execution of the Delta Project, which will radically alter the coastal currents off the west coast of the Netherlands, a careful watch must be kept on the movements of sand on the coast in order to prevent beach erosion and the silting-up of harbour entrances. A highly effective method of directly measuring littoral drift is to deposit a radioactively "labelled" quantity of sand at a point on the sea bed and thenceforth to monitor the activity in the surrounding area for a certain period. A rough calculation shows that very large amounts of radioactive materials (many curies) are required for this purpose. To investigate the problems involved, especially those relating to radiation protection, a preliminary experiment was made at the De Voorst hydrological laboratory by the Delta Authority in collaboration with the Philips-Duphar Isotope Laboratory. The tracer material consisted of glass beads made radioactive (isotope ^{24}Na) by irradiation in the Dutch-Norwegian nuclear reactor at Kjeller (Norway). In the actual measurements, now begun in the Haringvliet and at the mouth of the Rotterdam Waterway, use is made of ^{46}Sc, which has a more favourable half-life (85 days) than ^{24}Na and also emits a very suitable radiation. The deposited material must obviously have the same transport characteristics as sea sand. The experiment showed that this is by no means the case as far as the glass beads are concerned. The ^{46}Sc, however, can be bonded to a granular ion-exchange substance of the zeolite group (greensand, obtainable as "Ionac C 50"), which closely resembles North-Sea sand. To increase their hardness, the greensand grains are pre-fired at a high temperature.

AN EXPERIMENTAL DISC-SEAL TRIODE FOR 6000 Mc/s

by M. T. VLAARDINGERBROEK.

621.385.3.029.64

During the development work on the disc-seal triode type EC 157 [1]), it became clear that a frequency limit of 4000 Mc/s, and an output of 1.5 W at that frequency, did not constitute the utmost that could be achieved with triodes [2]). A triode capable of higher outputs — up to more than 10 W at 4000 Mc/s — has since been discussed in this journal [3]). With a metal-ceramic version of this valve in an oscillator circuit, it has been possible to step up the frequency to about 5000 Mc/s at an output of more than 10 W [4]). In the following a brief account will now be given of an experimental triode developed for amplifying signals in the 6000 Mc/s band (wavelength approximately 5 cm). This triode was tried out in an amplifier largely analogous to those made for the EC 157 and EC 59 valves. In this amplifier an average valve of this type delivers an output of 1.5 W with a gain of 7 dB at 6000 Mc/s for a bandwidth of 100 Mc/s.

The considerations involved in the design of a microwave triode have been dealt with on several occasions in this journal and elsewhere [5]). It will therefore be sufficient here to compare the new triode with the EC 157 type.

Theoretical considerations show that, to obtain a satisfactory gain with a triode, the transit time τ_{kg} of the electrons between cathode and grid must not be much greater than half the period of oscillation T of the electrical signal. The ratio τ_{kg}/T is given by the formula:

$$\frac{\tau_{kg}}{T} = 6.7 \times 10^{-10} f \left(\frac{d_{kg}}{J}\right)^{\frac{1}{3}}, \quad \ldots \quad (1)$$

where f is the frequency in c/s, d_{kg} the cathode-grid separation in cm and J the current density in A/cm^2. For the EC 157 ($d_{kg} = 40$ μ, cathode area 0.07 cm^2) the relevant values at $f = 4000$ Mc/s and at the usual anode current of $I_a = 60$ mA, are $J = 0.86$ A/cm^2 and $\tau_{kg}/T = 0.45$. If we wish to obtain the same value of τ_{kg}/T in a triode for 6000 Mc/s, equation (1) indicates that we can increase the current density J or shorten the distance d_{kg}, or both. The current density is limited to approximately the above-mentioned value by the power dissipation of the anode. On the other hand, d_{kg} cannot be indefinitely diminished because, owing to total-emission damping, the distance of the potential minimum from the cathode (about 5 μ at $I_a = 60$ mA) must remain small with respect to the cathode-grid separation. If this were no longer the case, the electrons that reverse before that minimum and return to the cathode would traverse a considerable part of the high-frequency field and convey R.F. energy to the cathode. Since this energy is not then used for modulating the electron current to the anode, this means a loss in gain. Experiments made on the EC 157 at 4000 Mc/s showed that the influence of the returning electrons, for $I_a > 30$ mA, is negligible [6]). These considerations led to the choice of $d_{kg} = 25$ μ for the 6000 Mc/s triode. For the same cathode area and at $I_a = 60$ mA, we then have $\tau_{kg}/T = 0.57$, which is an acceptable value.

In order to design a resonant cavity around the valve that is still tunable at these higher frequencies, one might, with the same anode surface area, reduce the anode-grid capacitance by making the grid-anode separation d_{ga} longer. This, however, would mean increasing the anode voltage in order to draw the same anode current, which would involve difficulties in cooling, owing to the higher anode dissipation. Another possibility of maintaining the tuning facility is to make the dimensions of the *outer* walls of the cavity round the valve smaller than for the EC 157. For an amplifier designed on the latter principle (see below), triodes have been made in which $d_{ga} = 250$ μ, i.e. approximately the same spacing as in the type EC 157. At an anode D.C. voltage of 250 V this enables sufficient current to be drawn from the cathode (> 60 mA). The maximum tunable frequency for the amplifier employed is higher than 6500 Mc/s. For the same amplifier, valves have also been made in which $d_{ga} = 300$ μ, and these have proved to be tunable up to more than 7000 Mc/s;

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[1]) The EC 157 triode differs from the old type, EC 57, in having a cathode of longer life. The EC 57 is described in G. Diemer, K. Rodenhuis and J. G. van Wijngaarden, Philips tech. Rev. **18**, 317-324, 1956/57.

[2]) J. G. van Wijngaarden, Nouvelles possibilités des triodes à disques scellés, Onde électrique **36**, 888-892, 1956.

[3]) V. V. Schwab and J. G. van Wijngaarden, The EC 59, a transmitting triode with 10 W output at 4000 Mc/s, Philips tech. Rev. **20**, 225-233, 1958/59 (No. 8).

[4]) E. Mentzel and H. Stietzel, A metal-ceramic disc-seal triode for frequencies up to 6000 Mc/s, Philips tech. Rev. **21**, 104-108, 1959/60 (No. 3).

[5]) See articles [1]), [2]), [3]), and also H. Groendijk, Microwave triodes, Proc. Instn. Electr. Engrs. **105 B**, Suppl. No. 10, 577-582, 1958.

[6]) M. T. Vlaardingerbroek, Measurement of the active admittances of a triode at 4 Gc/s, Proc. Instn. Electr. Engrs. **105 B**, Suppl. No. 10, 563-566, 1958.

they require a somewhat higher anode voltage for the same anode current.

The losses in the anode resonant cavity are largely due to the absorption of high-frequency energy by the glass ring between grid disc and anode. By using a special hard glass — anode, cathode disc and grid disc are of molybdenum, whose expansion coefficient corresponds to that of various hard glasses and which is moreover a good electrical conductor — and by making the ring as thin as practicable, it was possible to keep the losses down to 15 to 20% of the power output.

The method of constructing the 5 cm triode differs from that of the type EC 157. A means was sought to simplify the greatest problem in the construction of a microwave triode, viz. that of achieving with adequate precision the very small spacing between cathode and grid. This simplification was reached by pre-assembling the parts shown darkly shaded in *fig. 1*. This assembly consists of two rings *5* and *6* of molybdenum which support respectively the cathode *1* and the grid frame *3* carrying the grid *2*; these rings are fixed with a precise separation by three rods *7* of synthetic sapphire. Sapphire was chosen for its great strength, its ability to withstand high temperature and for the ease with which it can be bonded to metal. We shall now discuss the fabrication of this cathode-grid assembly.

After the rods *7* have been bonded to the rings *5* and *6*, the grid frame *3* carrying the grid wires *2* is screwed to the ring *6*. The resultant assembly is then placed in an aligning jig (*fig. 2*) with the plane of the grid wires *2* exactly perpendicular to the spindle *A* of the jig and with the grid electrically insulated from that spindle. The cathode *1* is clamped in a sleeve *B* set in a chuck *T* on the spindle, the sleeve being pushed between the tantalum foil cylinder *8* and the cathode. With the screw *S* the spindle *A* is now moved axially until the cathode surface just touches the grid wires. Because the grid is insulated from the cathode, this contact can be detected with a short-circuit meter. The cathode is then screwed back to give the required separation as indicated by the dial gauge *M*. The problem of

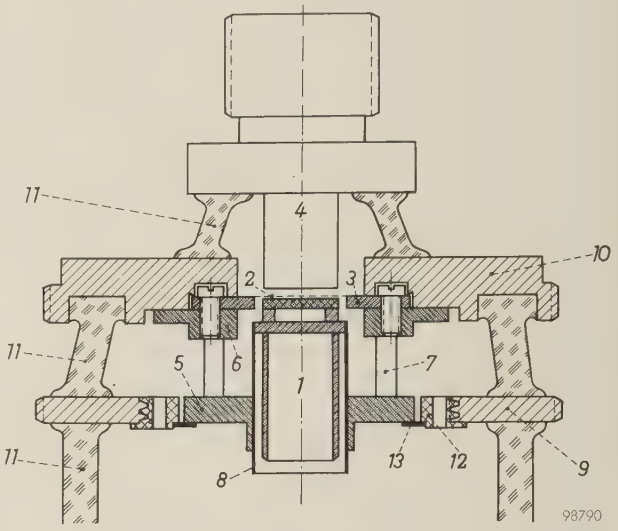


Fig. 1. Construction of the 5 cm triode. The darkly shaded section is pre-assembled. *1* cathode. *2* grid. *3* grid frame. *4* anode. *5* cathode ring (molybdenum) with welding collar (nickel). *6* grid ring (molybdenum). *7* sapphire rods joining the rings *5* and *6*. *8* tantalum foil cylinder of cathode, welded to the nickel collar of cathode ring. *9* cathode disc. *10* grid disc. *11* glass envelope rings. *12* closing ring with pump holes. *13* contact foil.

obtaining plane-parallelism between grid plane and cathode surface is relegated in this way to the construction of the jig. Backlash of the spindle is eliminated by the spring *V*.

When the cathode is at the desired distance, the tantalum foil *8* is welded to the cathode ring *5*. One difficulty here was that the last step, being a

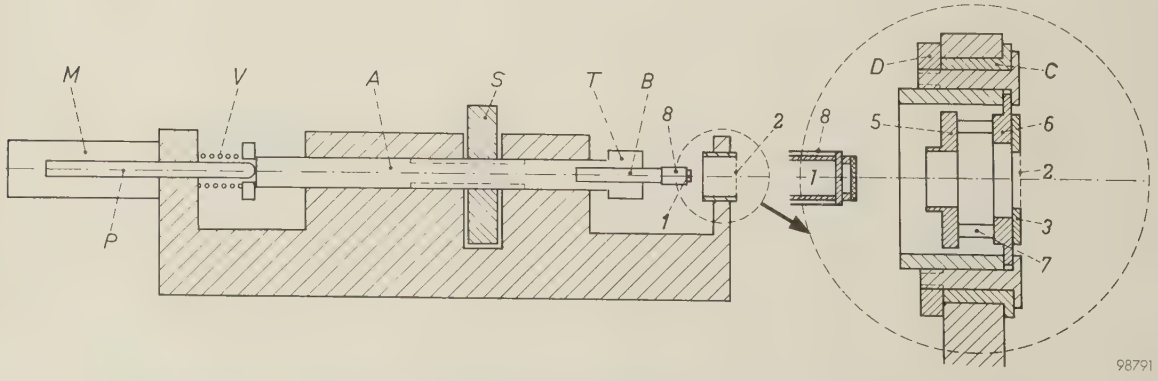


Fig. 2. Sketch of alignment jig for cathode-grid assembly. The valve components are numerically denoted as in fig. 1. *C* insulating ring of polytetrafluorethylene. *D* insulating ring of ebonite. The movable spindle *A* carries cathode *1* by means of the sleeve *B* mounted in the chuck *T*. *S* adjusting screw. *P* plunger of dial gauge *M*. *V* spring to prevent backlash.

welding operation, might cause plastic deformation of the tantalum foil and thus change the adjusted distance. It was found necessary to use nickel for the welding collar of the cathode ring, in which case only a light weld is needed to secure the tantalum foil. Plastic deformation is then negligible. Microscopic examination of a series of cathode-grid assemblies fabricated in this way showed that the cathode-grid spacing remained true to the adjusted spacing (approx. 47 μ) within 1 to 2 μ, and that the plane-parallelism was also good. The tantalum foil cylinder is shorter than in the EC 157, so that the change in length as the cathode heats up is smaller. The "hot" cathode-grid distance is about 25 μ.

The cathode-grid assembly can now be mounted in the outer structure of the valve (fig. 1). The grid-anode spacing is adjusted in this structure, after sealing the glass rings *11*, by turning on a lathe the anode *4* and the lower face of the grid disc *10* against which the grid ring *6* abuts. The cathode-grid assembly is fixed with three screws to the grid disc *10*. The annular opening needed between cathode ring *5* and disc *9* for this operation, is closed by a ring *12*, which is screwed into the cathode disc and makes contact with the cathode ring via a foil *13*. Pump holes are drilled in the ring *12*.

Fig. 3 shows a photograph of the aligning jig and the triode. The entire assembly takes place in a dust-free space.

The amplifier was designed, with the cooperation of J. P. M. Gieles, on the same principle as adopted for the EC 157 [7]) and the EC 59 [8]) types. For

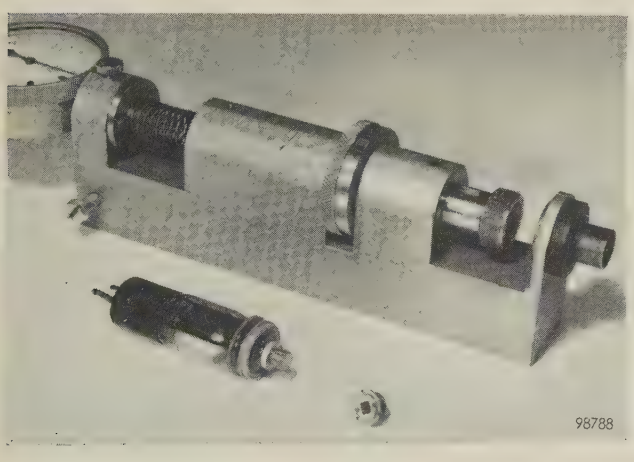


Fig. 3. Alignment jig, 5 cm triode and cathode-grid assembly (the latter with the grid to the fore).

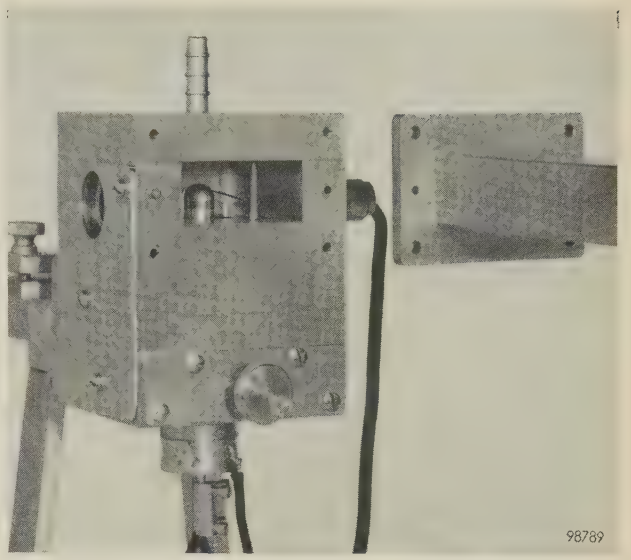


Fig. 4. Amplifier for the 5 cm triode, seen from the output side.

matching the amplifier to the input waveguide it was necessary to use a quarter-wave transformer. As in the amplifier for the EC 59, this was done by means of a ridge of length about a quarter wavelength inside the input waveguide [8]). Use is again made of additional reactive elements in order to correct for spread in the characteristics of individual valves. The bandwidth of the cathode circuit is greater than 500 Mc/s. At the output side the design differs from that for the EC 157 in that the inner conductor of the coaxial line is screwed to the anode. The principle, however, is the same. The amplifier can be seen in *fig. 4*.

Fig. 5 shows the static characteristics measured on an individual 5 cm triode. The transconductance is higher than 25 mA/V; the amplification factor is about 65.

The product of power gain G and bandwidth B of the anode resonant cavity is between 1000 and 2000 Mc/s for most of the valves tested (see *fig. 6*, measured on the same valve as fig. 5; the spread in $G \times B$ was found to be about $\pm 30\%$). It is noticeable that $G \times B$ is closely dependent on B (see caption to fig. 6). This is only partly explained by the fact that when B is small the losses in the anode cavity are considerably higher, amounting altogether to 20% at $B = 100$ Mc/s. The phenomenon is mainly attributable to internal feedback in the valve. This feedback is partly capacitative, partly inductive. The capacitative feedback is due to the anode-cathode capacitance (penetration — "Durchgriff" — of the alternating anode potential through the grid wires), and the inductive feedback may be represented by an inductive element in the grid

[7]) J. P. M. Gieles, Philips tech. Rev. **19**, 145, 1957/58.
[8]) J. P. M. Gieles and G. Andrieux, Philips tech. Rev. **21**, 41, 1959/60 (No. 2).

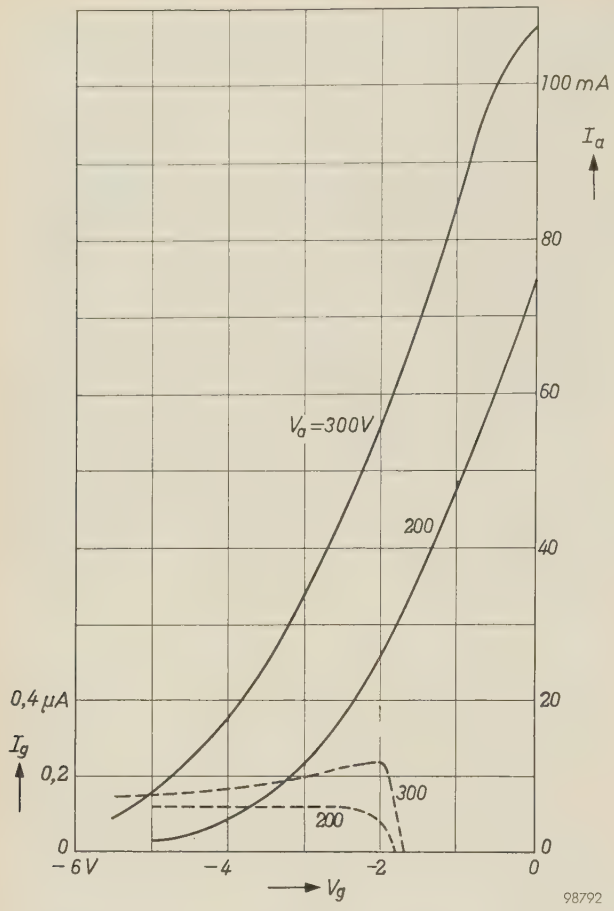


Fig. 5. D.C. characteristics of an average 5 cm triode.

lead [1]) [9]). Below the so-termed compensation frequency the capacitative feedback prevails, above this frequency the inductive. It can be shown that, below the compensation frequency, the product $G \times B$ must increase as B decreases. In the case of the EC 157, whose compensation frequency lies at approximately 5200 Mc/s, this is in fact found to be so at 4000 Mc/s. In the 5 cm valve triode, however, $G \times B$ is found to *decrease* with decreasing B (see fig. 6), from which it may be inferred that the operating frequency lies higher than the compensation frequency, i.e. that the inductive feedback is greater than the capacitive. If a grid with crossed wires were used, probably giving a smaller inductive feedback, it might be possible to increase the product $G \times B$ considerably for small B.

Fig. 7 shows the results of power output measurements made on the same valve to which figs. 5 and 6 refer. The curves show that an output P_o of 2 W is possible. At B = 100 Mc/s an output of 1.5 W is achieved with a gain of 7 dB, which is 3 dB lower than with a small P_o. If B is increased P_o decreases, the reason being that the anode impedance is then lower and P_o is limited principally by the maximum current drive.

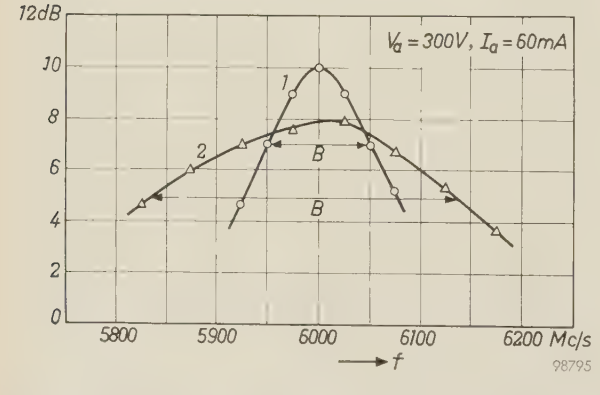


Fig. 6. The power gain in dB as a function of frequency at various bandwidths B, measured on the same valve as in fig. 5. The product $G \times B$ depends closely on B:
Curve *1* : B = 100 Mc/s, G = 10 dB, $G \times B$ = 1000 Mc/s;
Curve *2* : B = 300 Mc/s, G = 8 dB, $G \times B$ = 1850 Mc/s.

[9]) G. Diemer, Passive feedback admittance of disc-seal triodes, Philips Res. Repts. **5**, 423-434, 1950. See also the article mentioned under [7]), page 152.

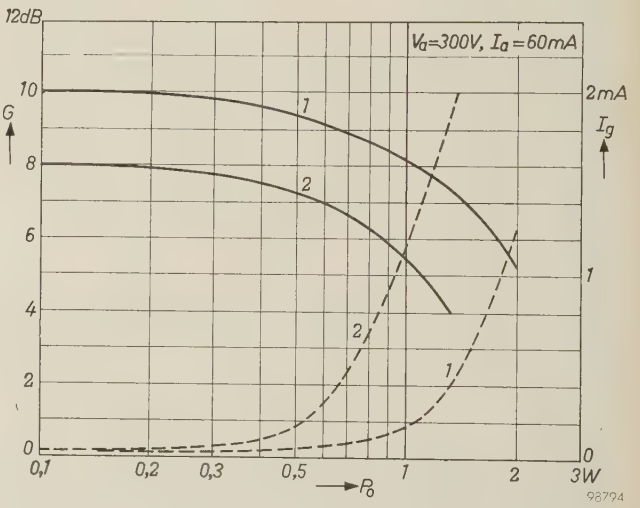


Fig. 7. Power gain G in decibels (solid curves) and grid current I_g (dashed) — which is required to remain within permissible limits — as functions of output power P_o at bandwidths of 100 Mc/s (curves *1*) and 300 Mc/s (curves *2*), measured on the same valve as in figs. 5 and 6. The amplifier input is matched for a low P_o.

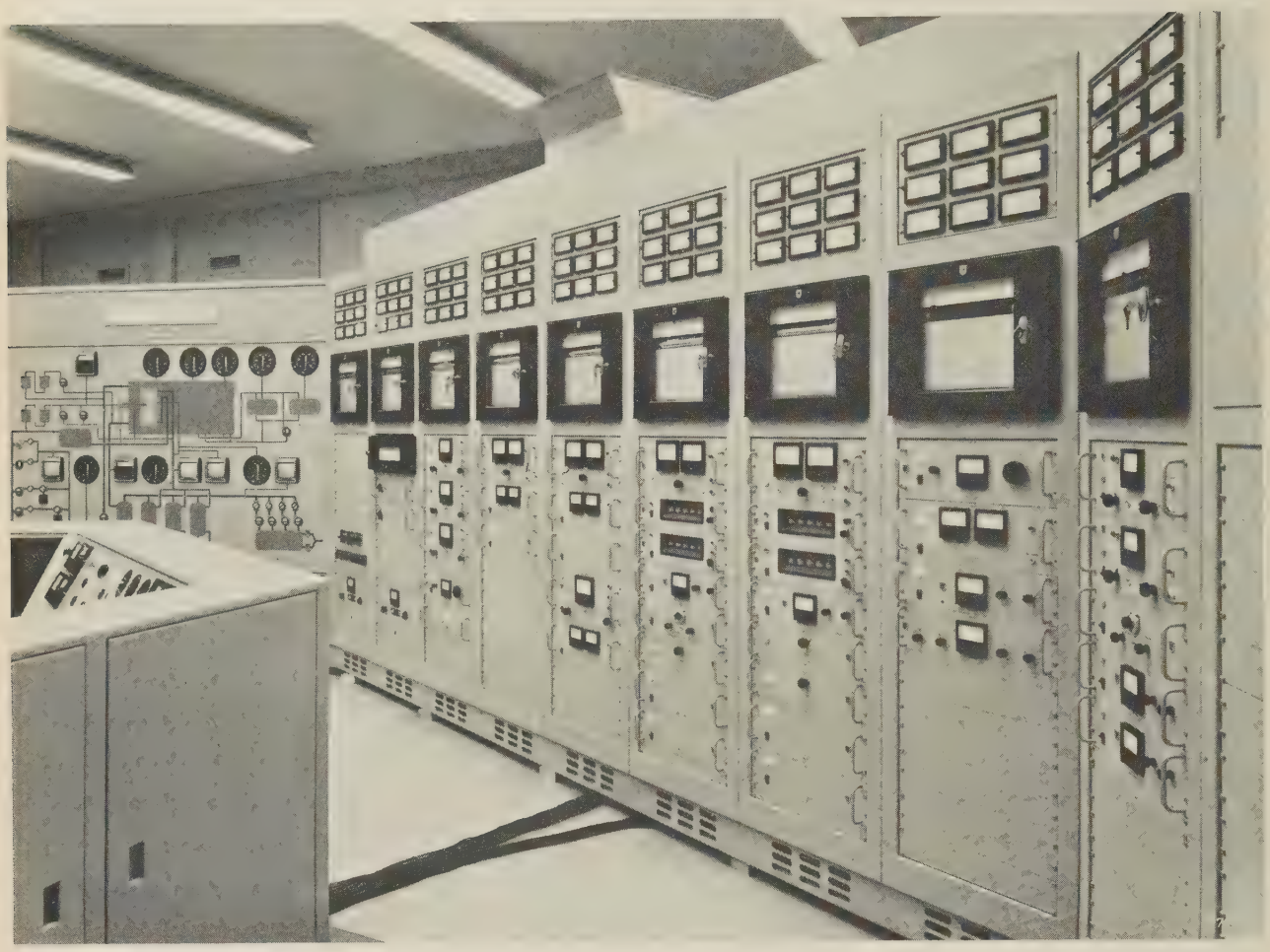
Suppose that the anode direct current is I_a and that the instantaneous value of the total anode current can be $2I_a$. In that case the r.m.s. value of the alternating current at the anode can reach $I_a/\sqrt{2}$. The anode impedance is $R_a = 1/(2\pi BC_a)$, where B is the bandwidth and C_a is the total capacitance of the anode circuit. The anode power is $(I_a/\sqrt{2})^2 R_a$; if B is 100 Mc/s, C_a is 1 pF and I_a is 60 mA, this represents about 3 W. The amplitude of the alternating anode voltage is then $I_a R_a \approx 100$ V, so that at a direct anode voltage of, say, 300 V there is comparatively little voltage modulation. The above considerations, which disregard feedback and losses, make it clear that it is the current drive that determines the relation between output power and gain.

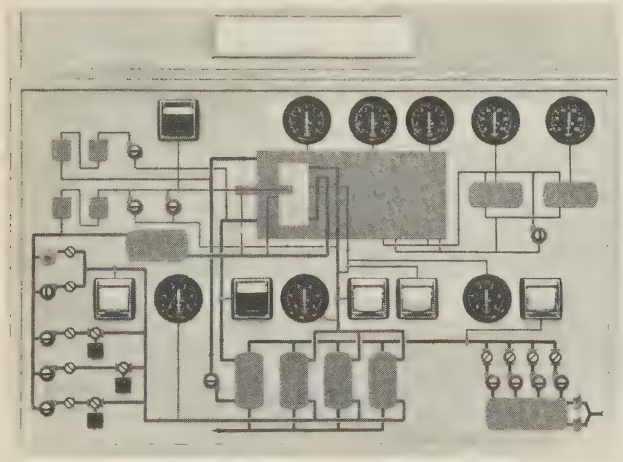
Finally, a few words about the valve as an oscillator. It was a simple matter to make an oscillator for 1.5 W output at 6000 Mc/s by feeding back part of the output to the input of the amplifier described. With the valves having a small grid-anode spacing this oscillator can reach a frequency of 6500 Mc/s. With the valves of larger grid-anode spacing a frequency of 7400 Mc/s has been achieved, but the power output is than lower. If the valve is incorporated in a suitable oscillator circuit, for example of the re-entrant type, even higher frequencies and outputs will certainly be possible, although this has not actually been demonstrated experimentally.

Experience gained in building this 5 cm triode, and the measurements made on it, justify the conviction that the upper limit of the frequency range at which triode amplifiers can operate with a sufficiently high $G \times B$ product has not yet been reached.

Summary. Brief description of an experimental disc-seal triode for 5 cm waves. The cathode-grid spacing is smaller than in the EC 157 and is achieved by pre-assembling these electrodes and adjusting the spacing in a precision jig. It amounts to about 25 μ with hot cathode. At a grid-anode spacing of 250 μ, made possible by reducing the outer dimensions of the anode resonant cavity, and at an anode voltage of 250 V, the highest tunable frequency of the amplifier designed round this valve is more than 6500 Mc/s; with 300 μ and a somewhat higher anode voltage it is more than 7000 Mc/s. With an average valve in this amplifier the product of power gain and bandwidth is 1000 to 2000 Mc/s. At 6000 Mc/s and a bandwidth of 100 Mc/s the power output is 1.5 W and the gain 7 dB. The losses amount to 15 to 20% of the output.

INSTRUMENTATION FOR THE PETTEN REACTOR





Near the village of Petten a 20 MW nuclear reactor is being built for the Netherlands Reactor Centre. The reactor is of the high neutron-flux type, and will be used for materials testing. Philips will supply the monitoring, control and safety equipment. The above photograph, taken at Eindhoven, shows the equipment in the final stage of assembly.

The equipment comprises instruments for measuring and controlling neutron flux, for safety monitoring, for measuring radiation density in the vicinity of the reactor, and for keeping a check on the radioactivity of cooling water and waste gases [1]). The instruments relating to the cooling circuit are on the graphic panel on the left (background of the photograph; a close-up is given in the smaller photograph). The circuit itself is represented schematically on the instrument panel.

([1] Installations designed for other types of reactor were described in Philips tech. Rev. **19**, 245-257, 1957/58, and Philips tech. Rev. **19**, 273-285, 1957/58 (swimming-pool reactor), and Philips tech. Rev. **21**, 109-152. 1959/60 (No. 4/5) (subcritical homogeneous suspension reactor).

METAL VACUUM EQUIPMENT

by N. WARMOLTZ and E. BOUWMEESTER.

533.599:621.791.856.3

It was not until the technique of arc-welding in rare-gas atmospheres was developed that it became really practicable to make vacuum-tight welds in the materials commonly used for vacuum apparatus — steel, non-magnetic chrome-nickel steel, aluminium, nickel and copper. In this welding technique, the electrical discharge between the workpiece and the electrode is shielded by a stream of a rare gas that displaces air from the vicinity of the hot metal, thus obviating oxidation.

The rare gases used — helium or argon in the United States, argon in Europe — are particularly suitable not only by virtue of their chemical inertness, but also because they are scarcely soluble in the metals named. If a gas is used that does dissolve easily in the molten metal, it escapes when the metal is setting, and pores or cracks may form in consequence. For example, hydrogen, which is fairly suitable for the welding of iron and milt steel, is quite unsuitable for welding alloys containing nickel, such as stainless steel [1]).

The possibility of making vacuum-tight welds in the metals normally employed in vacuum technique opens the way to the construction of leak-free metal components for vacuum systems. Such components can be assembled into systems which, besides being robust and highly vacuum-tight, can be efficiently degassed. Here we shall describe a number of such components, all of which have been welded in argon, and also a complete system which has been built up from them and which is suitable for a wide range of applications.

Of course the advantages just mentioned can be obtained by brazing as well as by welding. However, chrome-nickel steel — a material commonly used for vacuum equipment — cannot be brazed unless a firm layer of some other material has first been applied; moreover, the brazing of large and complicated workpieces is by no means an easy matter. Hence welding is generally to be preferred to brazing, and often enough it is the only practicable method [2]).

Our first example of an all-metal component is the cold trap shown in section in *fig. 1*. The trap has a particularly low flow resistance (high conductance). A cold trap of the same dimensions could of course be made of glass, but it would be fragile, and the connection to the vacuum system would give rise to some difficulty. A thick mantle of silica aerogel surrounds the vacuum chamber proper to provide thermal insulation. In this way the consumption of liquid air is reduced to less than 2 l in 24 hours. The trap is particularly suitable for mounting above the inlet of a mercury diffusion pump. The union between trap and pump will of course depend on the

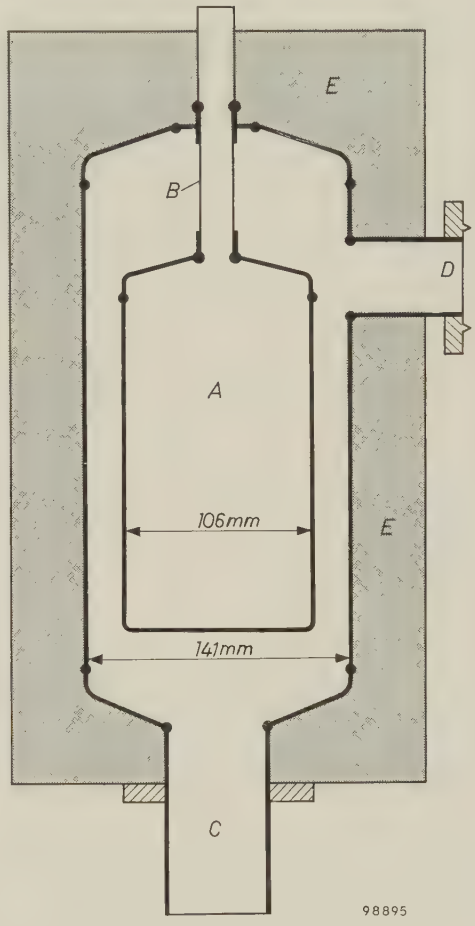


Fig. 1. Sectional diagram of an all-metal cold trap in stainless steel (18% Cr, 8% Ni, 74% Fe). Container *A*, holding about 1.5 l of liquid air, is suspended from tube *B*, which has a very thin wall in order to reduce its thermal conductivity. The trap is designed to fit on to a mercury diffusion pump, the connection being at *C*; at the temperature of liquid air (—183 °C) the trap has a conductance of 18.7 l/s for nitrogen. By allowing the trap to warm up slightly once every 7 to 10 days — during weekends for example — the mercury that has deposited on the outside wall of *A* has a chance to melt and to drip back into the pump of its own accord. The trap can be connected up to the vacuum system at *D*. Space *E* is filled with silica-aerogel insulation. Dots on the lines indicate argon-welded joints.

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[1]) Cf. R. A. Weinman and I. Langmuir, General Electric Review **29**, 160, 1929.

[2]) A detailed account of the welding and brazing techniques employed in the manufacture of vacuum equipment may be found in W. Espe, Vakuumtechnik **4**, 51, 1955; argon arc-welding is described by N. E. Anderson in Welding J. **28**, 222, 1949.

design of the latter, and it is not therefore shown in the figure. The drawing does however, show (at *D*) the flange whereby the trap is attached to the rest of the system. All the components we shall go on to describe have flanges of this type, and it will therefore be as well to deal with them separately.

Fig. 2a is a more detailed drawing of a pair of these flanges. The flange on tube *1* has a rather blunt circular ridge *2*, immediately opposite a shallow circular valley in the flange of the other tube. A packing ring *3* made of fairly soft copper about 0.3 mm thick is placed between the two. The surfaces of the flanges, which should preferably be of stainless steel, must be highly polished: no scratches must be visible when they are examined under a glass giving tenfold magnification. Requirements for the copper packing need not be so strict: electrolytic copper, which does not have to be oxygen-free, is quite satisfactory. For tube diameters between 4 and 8 cm the flanges must be about 10 mm thick. If there is a glass-metal seal near the flange, it is advisable to give the flange a thickness between 15 and 20 mm, as otherwise the glass may break when the nuts of bolts *4* are tightened.

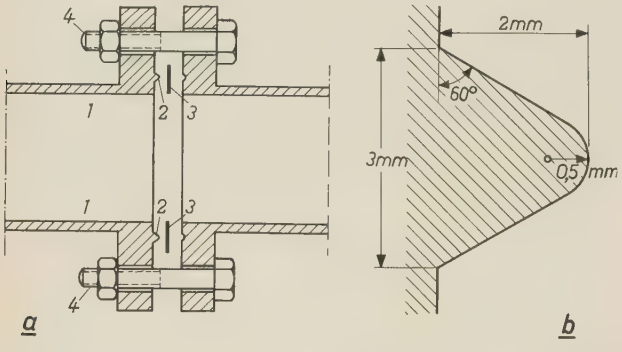


Fig. 2. Flanged joi nts between tubes in a metal vacuum system *a*) The flange on tube *1* bears a circular ridge *2* immediately opposite a circular score in the flange of the other tube. The packing *3* is of copper and is about 0,3 mm thick. The flanges are drawn together by a ring of bolts with a spacing of 2 to 3 cm. *b*) Section through the ridge *2*.

Experiments have shown that the joint just described can be maintained at a temperature of 500° C for 48 hours (e.g. for degassing) without undesirable effects. Nor do the nuts have to be tightened anew once the joint has cooled down. In view of the general need for degassing by heating, it is preferable to use copper as packing material rather than lead, which melts at a fairly low temperature, or aluminium, which flows and thereby necessitates retightening of the nuts.

The alternative method of connection illustrated in *fig. 3* can be employed for small tubes (diameter down to ~ 1 cm). Here the copper packing ring is clamped by the tube ends themselves, instead of by the flanges. Vacuum-tight welds are not therefore required.

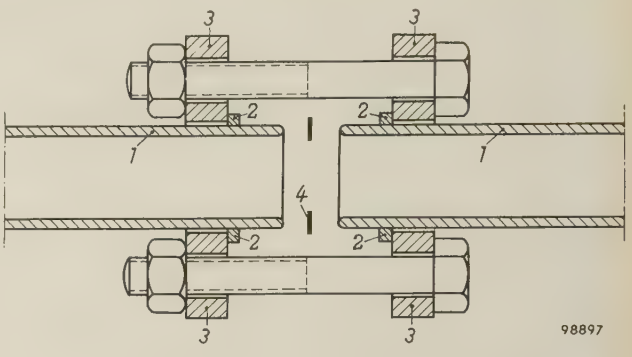


Fig. 3. Vacuum-tight joint directly between small tubes. The tubes *1* to be connected have their edges rounded off; *2* flanges welded on to tubes; *3* loose rings holed to take tiebolts; *4* copper packing ring.

We shall now discuss three vacuum valves, shown in *fig. 4*. The smallest is entirely of metal, while the two others embody a sealing ring made of "Teflon". When fully open, the largest valve has a conductance of 28 l/s for nitrogen, and hence it is very suitable as a pump isolating valve, for example. A cross-section of the valve is shown in *fig. 5*. The vacuum chamber is formed by the valve body *A* and the bellows *B*, both of which are made of stainless steel. The disc *D* moves on two guide rods *C* inside the valve body. The underside of the disc has a circular recess, rectangular in section and containing the Teflon sealing ring *E*. When handwheel *G* is turned, *D* moves downward and ring *E* is pressed on to the valve seating *F*. The Teflon ring, and the metal surfaces with which it comes into contact, are highly polished. An unsatisfactory seal in a valve of this type can easily be remedied by heating the closed valve for a short period, and so causing the Teflon to flow slightly. When open, the valve can be heated for a lengthy period to a maximum temperature of about 300 °C without suffering damage.

The design of the centre valve in fig. 4 is very similar to that of the one just described, closure again being effected by means of a Teflon ring. However, its conductance is lower (0.25 l/s). This valve is employed in gas inlet systems and in pipes to gauges.

Experience has shown that valves of either type hardly exhibit any wear or leakage after several years of service.

The smallest valve in fig. 4 (on the right) has an even lower conductance (0.1 l/s), but it has the advantage of being constructed entirely of metal; it can therefore be heated to a higher temperature than the two valves already described. It is not only

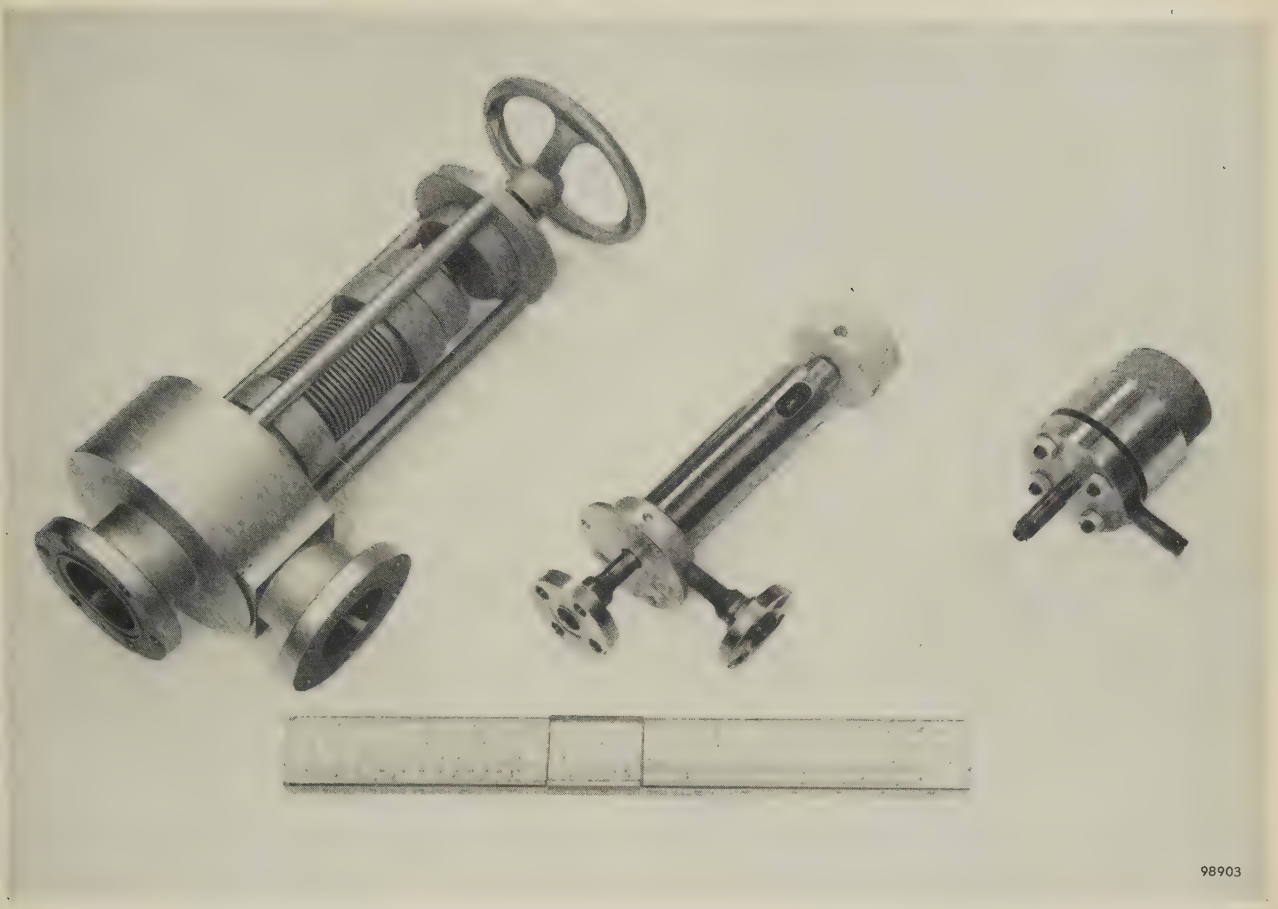
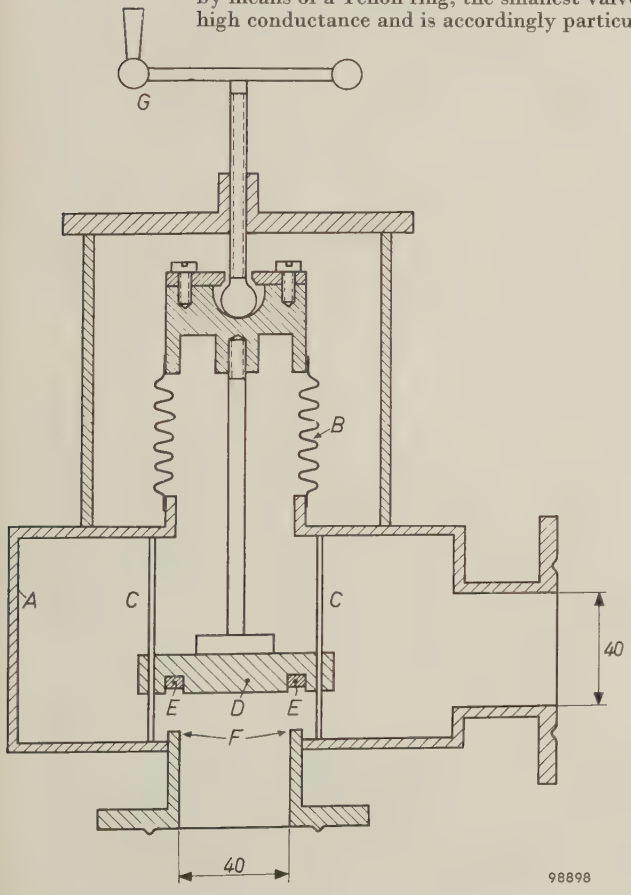


Fig. 4. Metal valves for use in vacuum equipment. In the two larger valves the seal is made by means of a Teflon ring; the smallest valve is entirely of metal. The largest has a very high conductance and is accordingly particularly suitable for use as a pump isolator.



in the absence of a Teflon seal that the design of the smallest valve differs from that of the other two, for a diaphragm (*A*, *fig. 6*) takes the place of the bellows. When new, these small valves have a leakage rate of less than 10^{-11} cm³/s. After they have been heated once or twice, the leakage rate becomes about 10^{-8} cm³/s. This low leakage makes the valve particularly suitable for use in gas inlet systems. Valves for such systems have to meet stringent requirements. While other kinds of vacuum valve normally only have to separate high from partial vacua, it is often necessary for gas inlet valves to seal off a storage chamber (at a pressure of 1 atm, say) from a high vacuum [3]).

[3]) These low leakage rates are measured, and the vacuum-tightness of components (and of complete systems) is investigated, with the aid of a small mass spectrometer used as a leakage detector. The lowest leakage rates that can be detected thus are of the order of 10^{-12} cm³/s. A description of an instrument of this kind may be found in N. Warmoltz and H. A. M. de Grefte, Le Vide **12**, 202, 1957.

Fig. 5. Sectional diagram of large metal valve with a Teflon seal. *A* valve body. *B* bellows. *C* guide rods for disc *D*. *E* Teflon ring. *F* seating on which Teflon ring is pressed. *G* handwheel on threaded spindle.

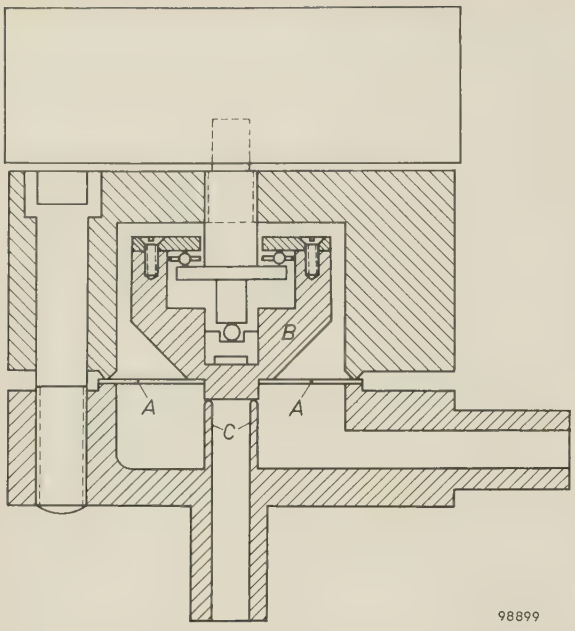


Fig. 6. Small all-metal valve. *A* diaphragm, *B* copper block that can be pressed against steel tube *C*.

above (fig. 1). The trap is connected via a large metal valve *D* having a Teflon seal (figs. 4 and 5) to a cylindrical chamber *E* on which are mounted an ionization gauge *J* (range 10^{-8} to 10^{-3} mm Hg) and a Penning gauge *P*. A flanged inlet is provided at the bottom of the cylinder, and to this the vessel or experimental apparatus *F* to be evacuated is attached. The pumping speed at the mouth of *B* is 30 l/s, and at the plane of the flange of *F* it has fallen off only to 10 l/s, as a result of using components of high gas conductance. Provided the system has been degassed sufficiently — for this purpose heating elements and thermal insulation are wrapped around *D* and *E*, and an oven surrounds *J* and *P* — it is possible to attain an ultimate pressure of 10^{-7} mm/Hg. If valve *D* is closed and evacuation continued with the ionization gauge alone, pressures down to 10^{-8} mm Hg can be reached [5]).

The purpose of the remaining part of the system is to enable the user to transfer to the vessel *F*

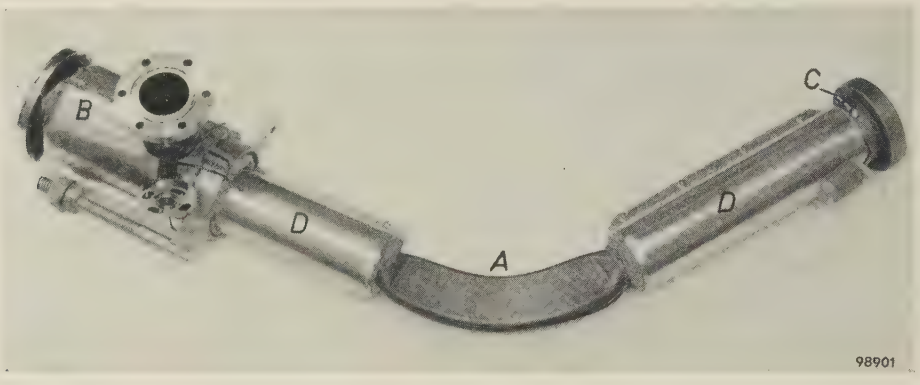


Fig. 7. Vacuum chamber for mass spectrometer. The curved central portion *A*, which is of copper, comes between the pole-pieces of a magnet when placed in the spectrometer. Connecting with the straight portions *D* are chambers *B* and *C* into which the ion source and the ion collector can be introduced. These chambers are made of non-magnetic stainless steel (25% Cr, 20% Ni). All parts were welded in argon except the steel-copper junction, which was brazed in a nitrogen atmosphere. The straight portions *D* visible in the photograph are actually heating mantles over the copper tubes.

Our last example of an argon-welded piece of vacuum equipment is the mass-spectrometer tube shown in *fig. 7*. Details of this component are given in the caption to the photograph.

The all-metal vacuum system mentioned earlier, which is suitable for a variety of applications, is shown diagrammatically in *fig. 8*. On the buffer tank *A*, which is exhausted by a rotary backing pump (not shown), is a mercury diffusion pump *B* [4]). Above that is a cold trap *C* of the type described

quantities of one or other of the gases stored in the containers marked *Z*. These connect via small metal valves *K* (fig. 6) with pipe *H*. This pipe can be evacuated separately via pipe *N*. For this purpose valve G_1 is opened and valve G_2 is closed; both are of the type illustrated in the middle of fig. 4. The diaphragm gauge *M* [6]), which has a range between 10^{-5}

[4]) Mercury is preferred to oil for the reasons explained in A. Venema and M. Bandringa, The production and measurement of ultra-high vacua, Philips tech. Rev. **20**, 145-157, 1958/59 (No. 6), in particular p. 149.

[5]) See for example p. 146 of the article cited under [4]).

[6]) A description of this type of gauge is given in J. J. Opstelten and N. Warmoltz, Appl. sci. Res. **B 4**, 329, 1955. The Penning gauge is described in F. M. Penning and K. Nienhuis, Philips tech. Rev. **11**, 116, 1949/50. The ionization gauge is described in E. Bouwmeester and N. Warmoltz, Philips tech. Rev. **17**, 121, 1955/56).

and 10 mm Hg, can be used to measure the pressure of gas admitted into *H* from one of the containers *Z*. The whole of pipe *H* and its appendages, including the diaphragm gauge, are wound with heating elements to allow them to be degassed (heating up to 150 °C). In order to obviate damage, the electrical heating of the diffusion pump is automatically switched off if there should be any failure in the supply of cooling water to the pump, and also if the pressure in *E* should exceed a certain value. A photograph of the system appears in *fig. 9*.

With an all-metal vacuum system such as described here work proceeds more quickly and reliably than in the case with a glass system, and there is no loss of time on maintenance routines such as the greasing of cocks. Furthermore, thanks to the absence of grease and rubber, a system of this kind can be degassed by heating it in its entirety.

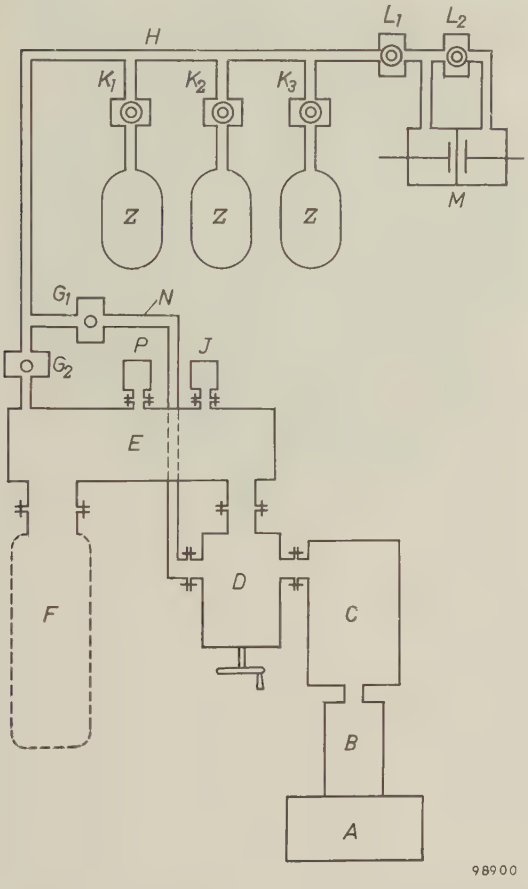


Fig. 8. Diagram of all-metal vacuum system with gas reservoirs. *A* buffer tank *B* mercury diffusion pump. *C* cold trap. *D* large metal valve with Teflon seal. *E* cylindrical chamber fitted with Penning gauge *P*, ionization gauge *J* and flanged connection to vessel *F*. *G* metal valves with Teflon seals. *H* tube for transfer of gas from reservoirs *Z* via small all-metal valves *K*; *M* diaphragm gauge with isolating valves *L*. The pipe *H* and its appendages can be separately evacuated via tube *N*.

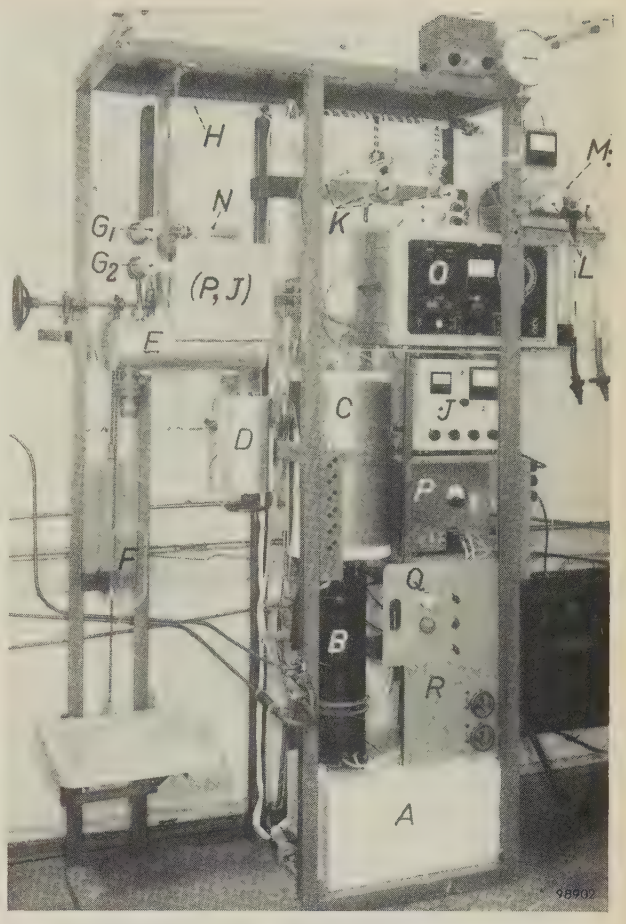


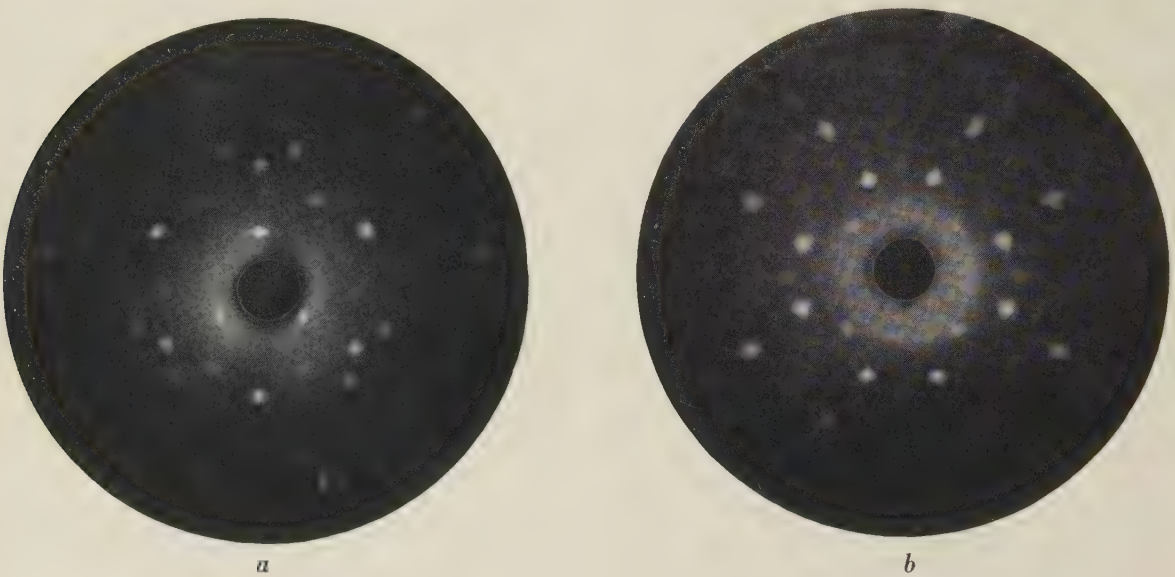
Fig. 9. Photograph of the vacuum system discussed in the text. The letters have the same meaning as in fig. 8; gauges *P* and *J* are behind the plate marked (*P*, *J*). The electronic circuits associated with the gauges, on the right of the photograph, are also marked *P* and *J*. *O* electronic circuit of diaphragm gauge *M*. *Q* switch panel, with fuse and pilot lamp. *R* panel carrying valve between tank *A* and rotary backing pump (not visible). All parts either have heating wires wrapped around them and, in some cases, insulation as well, or are located inside ovens (e.g. *P* and *J*).

Summary. The development of arc-welding in an argon atmosphere has opened the way to the construction of dependable vacuum-tight metal components for vacuum apparatus. The authors discuss components that have been produced with the aid of this welding technique, namely a cold trap and a vacuum valve, both of high conductance, two smaller valves, and a vacuum chamber for a mass spectrometer; they further describe the joints by which these components are coupled. The two larger valves are closed by a Teflon ring which presses against a metal seating; the smallest valve is entirely of metal. The packing material used for the joints is electrolytic copper. Finally, an account is given of an all-metal vacuum system which can be completely degassed and which is suitable for a large range of applications.

THE ORIENTATION OF DIAMONDS FOR TOOLS BY MEANS OF AN X-RAY IMAGE INTENSIFIER

621.9.027.2:621.386.8

Diamonds are nowadays used on a large scale in engineering industries. Because of its exceptional hardness, diamond is an ideal material for use in lathe bits, drills and grinders and for wire-drawing dies. The great demand for industrial diamonds and the comparative rarity of the mineral has led to the re-opening in recent years of closed mines and has also stimulated research in connection with the need to make the most economical and efficient use of the available stones [1]).



a *b*

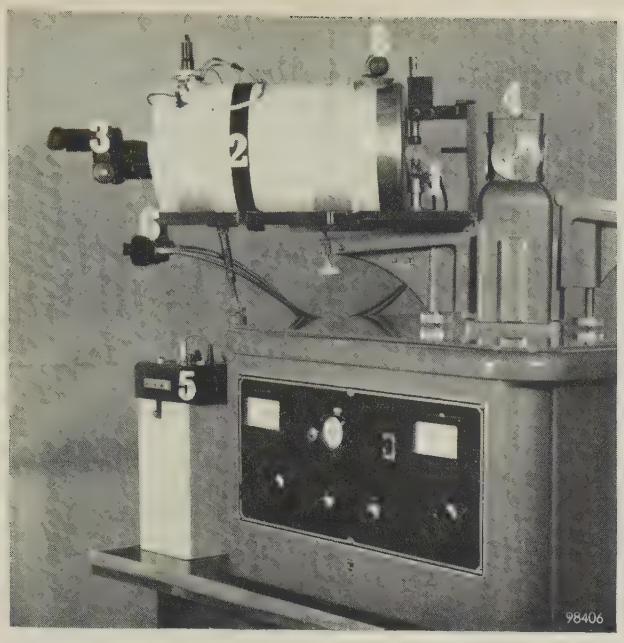
Fig. 1. Laue diagram of diamonds, the X-ray beam being parallel to one of the axes of symmetry.
a) Beam parallel to a three-fold axis, *b*) beam parallel to a four-fold axis.

One result of this research has been to show that a diamond has the longest useful life when it is given a very specific orientation in the tool. As is usual in a single crystal, many physical properties are not the same in all directions. The resistance of a diamond to wear, for example, shows a pronounced anisotropy. Accordingly, if the diamond is so positioned that the direction in which the workpiece moves along the tool coincides with the direction in which the diamond shows the greatest resistance to wear, the wear it suffers can be reduced to a minimum. Sometimes the life of a tool is not so much threatened by wear as by cleavage. In that case a different orientation is called for.

The directions in which the physical properties of a single crystal show maximum or minimum values are of course related to the structure of the crystal. To be able to set a diamond we must know the orientation of its space lattice. This can be seen from the outward appearance of some diamonds, and such stones can be set in tools accurately enough without special aids. For orienting the others the method of X-ray diffraction can best be employed. As is well known, the space lattice of a crystal can be found by directing a narrow parallel beam of X-rays upon the crystal and examining the directions in which the beam is diffracted. The spot pattern which the diffracted beams produce on a photographic plate is the familiar Laue diagram. From this it is essentially a simple matter to determine the axes of symmetry of a crystal; if an axis of n-fold symmetry is parallel with the X-ray beam, the spot pattern also shows n-fold symmetry (*fig. 1*).

The diffracted beams are so weak that a Laue diagram cannot be made directly visible by directing the beams on to a fluorescent screen. Until recently, the X-ray-diffraction method of orienting a diamond — compared with other methods, by far the most accurate — was therefore a time-consuming process; after every alteration in position, a photographic exposure was necessary to ascertain whether the diamond was any nearer to the desired

[1]) See e.g. L. Schultink, H. L. Spier and A. J. van der Wagt, The wear of diamond dies, Philips tech. Rev. **16**, 91-97, 1954/55.



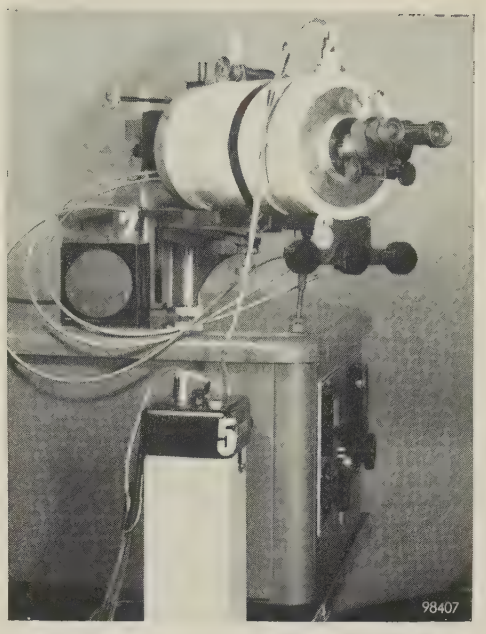


Fig. 2. Set-up for orienting diamonds, whereby the Laue diagram is observed with the aid of an X-ray image intensifier. *1* goniometer head on which the diamond is positioned; *2* X-ray image intensifier; *3* binocular viewer through which the intensified X-ray image is observed (the latter is 9 times smaller than the Laue diagram incident on the X-ray screen); *4* X-ray tube; *5* high-tension generator (25 kV) for supplying the image-intensifier tube; *6* controls with which the observer operates the goniometer head; *7* screen on which the desired diffraction pattern is optically projected for comparison purposes; the observer alters the position of the diamond until he observes in the image intensifier a pattern corresponding to the optical pattern on the comparison screen; *8* warning light, indicating that the X-ray tube is in operation.

orientation. This drawback of the X-ray-diffraction method has been removed by the advent of the X-ray image intensifier [2]), which permits direct visual observation of the Laue diagram. The process of orienting diamonds now takes only a few minutes and can be learnt by anyone in half a day.

Fig. 2 shows a set-up for orienting diamonds by the method described. The diamond is fixed to a goniometer head that can be remotely controlled by the observer behind the image intensifier. The observer alters the orientation of the diamond until he sees the desired spot pattern appear on the viewing screen. Since it is almost invariably possible (by inspection) to mount the diamond on the goniometer head in approximately the correct position, the orienting operation is, as said, relatively simple and rapid. Of course, the transfer of the diamond, thus oriented, to the holder in which it is to be set calls for a special technique, as developed, for example, in the Diamond Research Laboratory at Johannesburg, South-Africa [3]). The set-up shown in fig. 2 is located in this laboratory. A similar apparatus for orienting diamonds was built in Eindhoven some years ago [4]).

J. F. H. CUSTERS *) and A. J. van der WAGT.

[2]) See e.g. M. C. Teves and T. Tol, Philips tech. Rev. **14**, 33-43, 1952/53, and M. C. Teves et al., Philips tech. Rev. **17**, 69-97, 1955/56.

[3]) J. F. H. Custers, The orientation of diamonds for tools by means of an X-ray image intensifier tube, ASTE (Amer. Soc. Tool Engrs.) tech. Paper No. **104**, Coll. Papers **58**, Book I (1958). R. G. Weavind, C. J. Guykers and A. R. Roy, A rapid method of setting oriented diamonds in tools, ibid. Paper No. **103**.

[4]) See p. 95 of article [1]).

*) Diamond Research Laboratory, Johannesburg, South-Africa.

ABSTRACTS OF RECENT SCIENTIFIC PUBLICATIONS BY THE STAFF OF N.V. PHILIPS' GLOEILAMPENFABRIEKEN

Reprints of these papers not marked with an asterisk * can be obtained free of charge upon application to the Philips Research Laboratories, Eindhoven, Netherlands.

2655: H. C. Hamaker: Infusing statistics into industry (Bull. Inst. Int. Statistique **35**, 433-443, 1957).

The problems within industry to which statistics may be successfully applied are so many and varied that the solitary industrial statistician is not capable of coping with them all. One of his major tasks is therefore to teach others to apply statistical methods to their own problems. It is pointed out that the standard text books on statistics are not very suitable for this purpose. We should rather concentrate at once on the design of experiments, which is the most important chapter for the experimental scientist; and we should seek to explain the purposes and principles of a properly designed experiment and the corresponding analysis in simple terms without making too much use of a specific statistical jargon. How this can be achieved is illustrated by an example dealing with a foundry problem, where stacks, boxes within stacks, and moulds within boxes were the main factors entering into the analysis.

2656: H. de Lange Dzn.: Research into the dynamic nature of the human fovea-cortex systems with intermittent and modulated light, I. Attenuation characteristics with white and colored light (J. Opt. Soc. Amer. **48**, 777-784, 1958, No. 11).

A generally known method for the dynamic investigation of any linear system is recalled to mind. Applied to the visual organ with sinusoidally modulated light, the dynamic nature of the system fovea $\rightarrow$ visual cortex is embodied in attenuation characteristics, by plotting the ratio output amplitude over input amplitude against frequency at constant mean luminance. This manner of investigation, first applied in previous papers with white light, is expanded over a greater part of the range of cone vision and is continued with coloured light. The existing theories on flicker-fusion provide no explanation for the shape of the attenuation characteristics obtained from the experiments and calculated from investigations of other authors.

2657: H. de Lange Dzn.: Research into the dynamic nature of the human fovea-cortex systems with intermittent and modulated light, II. Phase shift in brightness and delay in color perception (J. Opt. Soc. Amer. **48**, 784-789, 1958, No. 11).

In this paper it is shown that the well-known residual brightness flicker just above the colour-flicker limit with heterochrome flicker photometry can be brought down to zero by introducing an external phase correction in one of two light beams sinusoidally modulated 100% in antiphase and simultaneously presented to the eye. The phase correction is found to be a function of luminance, colour difference, and frequency.

From the attenuation characteristic of the colour system it is found that the extra delay in colour perception at 595 mμ is consistent with a single integration process with a time constant of about 120 msec at high luminance; at low luminance a triple integration process seems to occur with the same time constant.

2658: R. Dijkstra and M. F. Lammers: On the determination of free phenol in phenol-formaldehyde resins (Rec. Trav. chim. Pays-Bas **77**, 933-934, 1958, No. 9/10).

The time necessary for the determination of free phenol in phenol-formaldehyde resins and moulding powders can be appreciably reduced by the addition of glycol to the resin during the steam distillation.

2659: G. Meijer: Influence of light on the elongation of gherkin seedlings (Acta bot. neerl. **7**, 614-620, 1958, No. 4).

Red and blue light have an inhibiting effect on the elongation of gherkin seedlings. A collaboration of blue and red light, given successively (B $\rightarrow$ R) or simultaneously (white light), however, has a much stronger inhibiting effect. This inhibiting effect can be neutralized by a subsequent irradiation with blue light; red or green light and darkness are ineffective in this respect.

2660: G. Meijer: The influence of light and of growth regulators on the elongation of gherkin seedlings (Acta bot. neerl. **7**, 621-626, 1958, No. 4).

The elongation of light-grown gherkin seedlings in blue light can also be obtained in red light in the presence of auxins. The elongating effect of blue

light on light-grown seedlings can be antagonized by anti-auxins. Light-grown seedlings transferred to darkness showed a toxic effect after a pre-treatment with blue or infra-red radiation. The same effect can be obtained by a pre-treatment with red light when auxins were added. Plants pre-treated with red light without an application of auxins did not show this typical effect.

2661: J. Kaashoek: Gradationsentzerrung im Farbfernsehen (Nachr.techn. Z. **11**, 515-518, 1958, No. 10). (Gradation correction in colour television; in German.)

Conventional methods of gamma correction in black-and-white television can be applied to colour television only to obtain a linear transfer characteristic. If these methods were used for gamma correction — often necessary for the transmission of transparencies and colour films — colour distortion would arise. This article discusses a new circuit which gives a controllable gamma correction dependent on the light absorption of the film, without colour distortion. The transfer characteristic of the system can be given any gamma value between 0.4 and 1. It is also possible to let the correction depend on the colours occurring in the picture, again without affecting the overall colour rendering.

2662: G. H. Jonker and W. Kwestroo: The ternary systems $BaO\text{-}TiO_2\text{-}SnO_2$ and $BaO\text{-}TiO_2\text{-}ZrO_2$ (J. Amer. Ceram. Soc. **41**, 390-394, 1958, No. 10).

An investigation of the ternary systems $BaO\text{-}TiO_2\text{-}SnO_2$ and $BaO\text{-}TiO_2\text{-}ZrO_2$ led to the discovery of two new compounds belonging to the system $BaO\text{-}TiO_2$., viz. $Ba_2Ti_5O_{12}$ and $Ba_2Ti_9O_{20}$. These compounds are stabilized by minute additions of SnO_2 or ZrO_2. The known compound $BaTi_2O_5$ can be obtained only from the molten phase and decomposes below 1300 °C into $Ba_2Ti_5O_{12}$ and $BaTiO_3$. In these systems no ternary compounds are found. The ternary phase diagrams can be divided into regions with high and low dielectric losses, which are in accordance with the phase relations. Tables with crystallographic data of the new compounds are included.

2663: F. A. Kröger: On the relation between non-stoichiometry and the formation of donor and acceptor centres in compounds (Phys. Chem. Solids **7**, 277-278, 1958, No. 2/3).

If the composition of a semiconductor compound deviates from the stoichiometric proportions (i.e. the composition defined by the simple chemical formula), donor and acceptor centres can occur. It is often assumed that one donor or acceptor centre occurs for every atom above the stoichiometric number. This is not necessarily the case, as is shown in this note.

2664: J. S. van Wieringen: La résonance paramagnétique comme moyen d'étude en recherche verrière (Verres et Réfractaires **12**, 256-260, 1958, No. 5). (Paramagnetic resonance as an aid in the study of glass; in French.)

The paper opens with a description of the principles of paramagnetic resonance (in which transitions between the energy levels of the elementary magnets of paramagnetic substances are measured). The apparatus used for such investigations is described. The author then examines why both paramagnetic glasses (as a result of their composition) and diamagnetic glasses irradiated by X-rays show paramagnetic resonance; in particular, investigation of the latter makes it possible to determine the structure of corresponding paramagnetic colour centres. A new method for the study of glasses is thus available, a method which has already given good results for paramagnetic salts, semiconductors, free organic radicals, etc.

2665: P. J. Papenhuyzen and P. Zijlstra: Une triode d'émission 10 kW pour télévision jusqu'à 220 Mc/s (Onde électr. **38**, 743-758, November 1958). (A 10 kW transmitting triode for television up to 220 Mc/s; in French.)

The first part of this paper concerns the design and properties of the transmitting valves TBW 6/20 (water-cooled anode) and TBL 6/20 (air-cooled anode). With a small output capacitance, large slope and large amplification factor, a bandwidth of 12 Mc/s is reached, as required for the French 819-line television system. The power amplification when used in grounded-grid configuration is large, viz. 9. The small output capacitance in conjunction with a small output self-inductance makes application in frequency band III (up to 216 Mc/s) possible. The valve is of the disc-seal type which facilitates mounting in a resonant cavity. The cathode has the form of a cage and is made of thoriated tungsten wire (mesh cathode). The second part of the paper describes a test transmitter in which the above two tubes are separately tested. The frequency of this transmitter is 216 Mc/s. From the tube dimensions, the dimensions of the resonant cavity are calculated. The are in good agreement with the dimensions of the cavity actually used. See also Philips tech. Rev. **19**, 118-128, 1957/58.

2666: J. L. Meijering and C. J. M. Rooymans: On the olivine-spinel transition in the earth's mantle (Proc. Kon. Ned. Akad. Wet. **B 61**, 333-344, 1958, No. 5).

The density gradient of the earth's mantle appears from seismic data to be greater than that to be expected from its compressibility. Bernal has suggested that this is due to a transformation of the olivine $(Mg,Fe)_2SiO_4$ (a major constituent of the earth's mantle) to a more close-packed structure, e.g. the spinel structure. The treatment of the earth's mantle as a one-component silicate system (Vening Meinesz) is found to be unsatisfactory. A treatment on the basis of the binary system Mg_2SiO_4-Fe_2SiO_4, on the other hand, gives more reasonable results. It is shown that the agreement might be further improved if the presence of still other silicates (such as $MgSiO_3$) were taken into account.

2667: T. J. de Man, E. J. ten Ham, J. R. Roborgh and N. Zwiep: Utilization of vitamin A from a stabilized dry preparation: comparative experiments with chickens (Netherl. J. agricult. Sci. **6**, 237-244, 1958, No. 4).

The utilization of vitamin A (continuously administered in low doses) from a stabilized dry preparation and from fish liver oil has been compared in experiments with chickens; these preparations were administered by mixing through the feed and by direct dosing into the beaks of the animals, respectively. Two criteria have been used: *a*) storage of vitamin A in the livers, *b*) growth. Modifications for both methods, permitting a quantitative statement of the results, have been developed. In order to obtain reliable figures, it was necessary to exclude any influence of differences in stability of the preparations investigated. Therefore, in the experiments during which the preparations were administered through the feed, this mixing was performed daily. The results, obtained by means of both criteria, lead to the conclusion that, aside from the question of stability, 1 I.U. of vitamin A in the form of the dry preparation, mixed through the feed, has the same biological activity in chickens as 1.3 I.U. of vitamin A in the form of fish liver oil. An experiment in which the mixing took place only once (5 weeks before the start of the experiment) resulted in an "activity ratio" of about 4.

2668: C. Wansdronk: Het meten van richtingsdiagrammen en overgangsverschijnselen aan luidsprekers (T. Ned. Radiogenootschap **23**, 303-309, 1958, No. 6). (The measurement of polar diagrams and transient phenomena of loudspeakers; in Dutch.)

Apart from the measurement of frequency and phase characteristics of loudspeakers, it is important to know their directivity pattern and transient behaviour. This article contains a description of the apparatus for rapid measurement of the latter two properties by making them visible on the screen of an oscillograph.

2669: J. W. L. Köhler: Fysische aspecten bij de ontwikkeling van koudgaskoelmachines (Ingenieur **70**, W. 175-W. 178, 5 Dec. 1958). (Physical aspects of the development of the gas refrigerating machine; in Dutch.)

Many problems linked with the Stirling process prove to be of a rather fundamental nature. The reason is that, whereas normal refrigerating apparatus consists of rather isolated equipment connected in series, the Stirling process is performed in a single machine, which combines all functions; this gives rise to a number of difficult cross-effects. Some examples of this are given — for instance the regenerator, which is the most interesting but difficult element of the machine. The cycle is interesting as a fine illustration of a reversible cycle; the results of its study may be used on a broad front, e.g. also for the hot-gas engine, the gas refrigerating machine and the heat pump.

2670*: K. Compaan and Y. Haven: Diffusion of tracers through solids (Proc. Internat. Symp. on Transport processes in statistical mechanics, Brussels, August 27-31, 1956, pp. 414-418; Interscience Publishers, New York 1958).

English translation of an article on indirect diffusion in crystals, already published in French as a chapter in the book "La diffusion dans les métaux", Philips Technical Library, 1957. See No. **2515** of these Abstracts and the short notice on p. 332 of Philips tech. Rev. **19** (1957/58).

2671: J. A. Kok: On superconductivity (Physica **24**, 1045-1050, 1958, No. 12).

This article deals with a two-component theory of superconductivity. At temperatures below the normal transition point the superconductor is assumed to consist of two components. One of these is the normal metal, whereas the second has a slightly larger volume $V + \Delta V$. The equilibrium between the electrons in the two states may be possible via the lattice vibrations. Some speculations are made on the normal transition temperature and on the question of what metals will become superconductive.

2672: H. J. Oskam and H. M. Jongerius: Helium-neon bands (Physica **24**, 1092-1094, 1958, No. 12).

In 1931 Druyvesteyn observed bands in the spectrum of helium-neon mixtures, which he attributed to a compound of helium and neon. The existence of these bands has since been doubted by others. From recent investigations (see e.g. Nos. **R 349** and **R 350** of these Abstracts), however, the existence of a molecule HeNe has been demonstrated by measurements of quite a different nature. The authors have therefore repeated Druyvesteyn's experiments; the results confirm his observations.

2673: M. J. Koopmans: A microdispersing apparatus for the use of biological investigation of chemicals (Meded. Landbouwhogesch. Opzoekingsstat. Gent **23**, 831-836, 1958, No. 3/4).

In investigations of the biological action of chemicals not soluble in water it is often required to put small quantities (10-50 mg) of them in the form of aqueous suspensions or emulsions. This article describes a mill suitable for grinding such preparations. A small glass vessel conically ground inside has a glass stop identically ground on its outside, which rotates inside it. The stop is supported from underneath, so that there remains a small play between stop and vessel. The conical stop has a flat on one side; in the space so left between stop and vessel the preparation and the water are introduced. A number of these mills are driven by an electric motor. After about 10 minutes the maximum particle size is 10 μ or less, dependent on the nature of the substance. The mean particle size is usually less than 2 μ.

2674: J. Brug, C. A. de Bock, H. D. Moed and A. J. Klein: Antiviral action of derivatives of ω-aminoacetophenone (Brit. J. Pharmacol. Chemother. **13**, 404-410, 1958, No. 4).

Numerous structural analogues of 3-amino-4-hydroxy-ω-methylaminoacetophenone were tested for their effect on the multiplication of influenza virus (FM_1 strain) in embryonated eggs, infected via the allantoic cavity. Antiviral activity was found in ω-aminoacetophenones containing an amino and hydroxyl group in the aromatic nucleus in the *ortho* or *para* positions to each other. The most powerful antiviral activity was found in the series of ω-alkylamino-5-amino-2:4-dihydroxy-acetophenones. Derivatives of acetophenone with other substituents in the aromatic nucleus or in the aliphatic chain were without activity. *In vitro*, the analogues exert a virucidal action. No inhibition of virus multiplication occurred in embryonated eggs infected via the yolk sac, or in mice infected intranasally with FM_1 virus. The activity in the allantoic test could be explained by the virucidal action of the compounds on the virus present in the allantoic fluid. No satisfactory interpretation of the empirical relationship between chemical structure and antiviral activity could be found.

2675: M. T. Vlaardingerbroek: Measurement of the active admittances of a triode at 4 Gc/s (Proc. Instn. Electr. Engrs. **105 B**, Suppl. No. 10, 563-566, 1958).

The paper describes the method of measuring the active admittances of the EC 57, a 4 Gc/s microwave triode. The results prove to be in reasonable agreement with the transit-time theory if the current density is sufficiently high.

2676*: J. H. Spaa: Algunos procedimientos para la producción de neutrones rápidos y monoenergéticos (Ciclo de conferencias celebrado con motivo de la exposición "El átomo y sus aplicaciones pacíficas", pp. 155-168; Sindicato Nacional de Agua, Gas y Electricidad, Madrid 1958). (Some methods for the production of fast mono-energetic neutrons; in Spanish.)

Report of a lecture given in Madrid on 21 May 1958. After a review of nuclear reactions potentially suitable for producing fast mono-energetic neutrons, two equipments for this purpose built in the Philips Research Laboratories are described. The first is a neutron generator based on the D-D reaction and using a 1 MV high-tension generator built in a tank pressurized with nitrogen at 10 atm. The neutrons are generated on the edge of a rotating dish containing heavy ice; cooling is effected by a liquid-air supply. The second equipment is a sealed-off neutron tube using a Penning ion source. Deuterons are accelerated and bombard tritium atoms absorbed on a zirconium target.

2677*: J. H. Spaa: Algunos nuevos métodos para detectar la contaminación radiactiva del aire y del agua (Ciclo de conferencias celebrado con motivo de la exposición "El átomo y sus aplicaciones pacíficas", pp. 173-187; Sindicato Nacional de Agua, Gas y Electricidad, Madrid 1958). (Some new methods for the measurement of the radioactive contamination of air and water; in Spanish.)

Report of a lecture given in Madrid on 23 May 1958. After some general considerations of the prin-

ciples of "Health Physics", two equipments developed in the Philips Research Laboratories are described. With the one equipment, which uses a special compensation technique, it is possible to detect and measure radioactive contamination of the air above the natural radioactivity. The apparatus works automatically, taking air samples and making measurements step-wise. The other apparatus is for the measurement of the β-activity of samples of very low activity. It consists of a mica-window geiger tube mounted in the hollow anode of a second geiger tube which is connected in anti-coincidence with the first. The whole is surrounded by a radiation shield. By suitable choice of materials, the design of the inner tube and the presence of the outer guard tube, an extremely low background is obtained. In this way extremely small activities can be measured in quite a short time.

2678: G. Meijer: The influence of light quality on the photoperiodic response of Salvia occidentalis (Acta bot. neerl. **7**, 801-806, 1958, No. 5).

Salvia occidentalis is a tropical plant which normally blooms only when the daily light period is shorter than a certain critical time (short-day plant). Earlier investigations by the author (see Nos. **2547** and **2548** of these Abstracts) showed that the blue and the infra-red components of the light hinder blooming. The investigation described here is concerned with whether this effect can be neutralized by suitable irradiation with red light.

2679: H. J. G. Meyer: Infrared absorption by conduction electrons in germanium (Phys. Rev. **112**, 298-308, 1958, No. 2).

Infra-red absorption by mobile charge carriers in semiconductors is governed by the band structure and the various scattering mechanisms. Measurement of this absorption therefore yields information on the band structure and the scattering. In this paper a quantum-mechanical theory is developed in which the multiple valley structure of the conduction band is taken into account. Using scattering theory in which a deformation potential is introduced, a fairly exact calculation can be made for all wavelengths and temperatures of interest. The result for the absorption due to normal vibrations of the acoustic branch contains two deformation-potential constants. Filling in the known values of these constants one finds, however, that the absorption coefficient at $\lambda = 10^{-3}$ cm and a temperature of 78 °K is a factor 5 too low with respect to the experimental value of Fan and Spitzer. This discrepancy can be eliminated by assuming that the normal vibrations of the optical branch also have an appreciable effect on the absorption. An estimate can then be made of the interaction between a conduction electron and these optical normal vibrations. With a simpler model an estimate is also made of the effect of impurity-centre scattering on the absorption coefficient. With the aid of this estimate, concentration, wavelength and temperature limits are given within which impurity-centre scattering can be neglected. The general limits of validity of the theory are given.

2680: H. Groendijk: Microwave triodes (Proc. Instn. Electr. Engrs. **105 B**, Suppl. No. 10, 577-582, 1958).

The valves treated in the paper are triodes with plane electrodes intended to be used as amplifier valves, local oscillators and transmitting valves in repeaters working in the super-high-frequency region. The most important factor in their design is the product of power gain and bandwidth. It is shown that this product is chiefly determined by valve parameters. For a high value of the gain-bandwidth product, a high current density and a small cathode-grid distance are needed, resulting in a small electron transit time. A transit time of 1.3×10^{-10} sec has been obtained. Although the deviations of input conductance and transadmittance from their D.C. values — due to transit-time effects — are considerable, these deviations have only a small influence on the gain-bandwidth product. A table is given showing constructional and electrical data for a number of microwave triodes, of which one is in production. The others are in the experimental stage of development. The paper discusses the following properties of an amplifier with a microwave triode: (*a*) Gain-bandwidth product, 2 Gc/s. (*b*) Noise figure, 16 dB. (*c*) Variation of group-delay, 0.06 millimicrosec. (*d*) Amplitude-phase conversion, 0.8 deg/dB. The figures mentioned are obtained with an amplifier stage equipped with an EC 57, a triode for operation at 4 Gc/s.